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Population Status of Eastern Georges Bank Cod (Unit Areas 5Zj,m) for 1978-2002

État du stock de morue de l'est du banc Georges (zones-unités 5Zj,m) pour la période 1978-2002

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Abstract

An analytical assessment of the Georges Bank cod stock in 5Zj,m was completed using updated catch-at-age for ages 1-10 and research survey indices. A revised ADAPT formulation, based on TRAC recommendations involving a reduced number of RV indices and direct estimates for 1997-2000 F_{oldest} , was used to characterize the population. Results of the assessment provided statistically significant parameter estimates for the 2002 beginning-of-year population at ages 2 through 10**.** Bias and precision for the estimates were within acceptable limits. The adult biomass increased from the low of 8,900t in 1995 to about 21,100t at the beginning of 2001, primarily due to survival and growth of the 1992, 1995 and 1996 year-classes. Since 2001, adult biomass has declined and was about 17,300t at the beginning of 2002. Exploitation rate on ages 4-6 decreased from more than 50% in the mid-1990's to below the $F_{0.1}$ reference level in 1999-2000 but increased to 20% in 2001. A change in partial recruitment to the fishery has occurred since 1994 with reduced catchability on ages 5+. This change is due to the bycatch nature of the fishery and to management measures that reduced spatial and temporal access to the resource. Recruitment in recent years has been poor, with the 1992, 1995 and 1996 year-classes being moderately stronger than adjacent year-classes. The 1998 year-class appears to be above the recent average**.** Projections for 2002 indicate a yield of about 1,900 t at $F_{0.1}$ and the stock biomass will remain stable between 2002 and 2003. Only at 2002 yields of 1,000 t or less is there a 50% or better chance of a 10% increase in biomass. The adult stock biomass remains below a threshold of 25,000 t, above which chances of good recruitment are improved.

With the current poor recruitment and exploitation rates near the present levels, improvement in stock status is not expected in the near term.

Résumé

Nous avons effectué une évaluation analytique du stock de morue du banc Georges dans 5Zj,m à partir de données à jour de captures par âge des poissons de 1 à 10 ans et d'indices obtenus par des relevés de recherche. Nous avons caractérisé la population en appliquant une procédure ADAPT révisée fondée sur les recommandations du Transboundary Resources Assessment Committee (TRAC), un nombre réduit d'indices obtenus par navire de recherche et des estimations directes pour la période 1997-2000. L'évaluation a donné des estimations statistiquement significatives de paramètres de la population de morues âgées de 2 à 10 ans au début de l'année 2002. Le biais et la précision des estimations se situaient dans les limites acceptables. La biomasse des adultes est passée de son niveau le plus bas, soit 8 900 t, en 1995 à environ 21 100 t au début de l'an 2001, surtout en raison de la survie et de la croissance des classes d'âge 1992, 1995 et 1996. Depuis 2001, la biomasse des adultes a diminué; elle se chiffrait à environ 17 300 t au début de l'an 2002. Le taux d'exploitation des morues de 4 à 6 ans a baissé, passant de plus de 50 % au milieu des années 1990 à une valeur inférieure au niveau de référence F0,1 en 1999-2000, puis a augmenté à 20 % en 2001. Étant donné la capturabilité réduite des morues de 5 ans et plus, le recrutement partiel a changé depuis 1994, ce qui s'explique par le fait qu'il s'agit d'une pêche accessoire et par les mesures de gestion qui ont réduit l'accès à la ressource, tant sur le plan spatial que temporel. Ces dernières années, le recrutement a été faible, mais les classes d'âge 1992, 1995 et 1996 sont modérément plus fortes que les autres. La classe d'âge 1998 semble un peu plus forte que la moyenne des années récentes. Les prévisions pour l'an 2002 indiquent que la production sera d'environ 1 900 t pour une exploitation à F0,1 et que la biomasse du stock restera stable de 2002 à 2003. En 2002, la production ne devra pas dépasser 1 000 t pour obtenir une probabilité d'au moins 50 % que la biomasse augmente de 10 %. La biomasse des adultes du stock se maintient sous le seuil de 25 000 t, au-delà duquel les chances d'obtenir un bon recrutement augmentent.

Les taux d'exploitation et le faible recrutement actuels ne laissent pas entrevoir une amélioration de l'état du stock à court terme.

Introduction

This report incorporates commercial catch data and research survey results for the 1978-2002 time period to estimate the stock status of cod in the two NAFO unit areas 5Zj and 5Zm (5Zj,m) (Figure 1). Definition of this management unit was based on analysis of tagging results and commercial and survey catch distribution (Hunt, 1990). Hunt and Hatt (2001) reported the status of the stock in 2000 (DFO, 2001).

Cod are taken in 5Zj,m by both Canada and the USA and all data relating to USA catches and research vessel surveys were provided by the National Marine Fisheries Service (NMFS) at the Woods Hole, Mass., Laboratory.

A benchmark review of the model used for the assessement of cod in 5Zj,m was conducted in February, 2002 (TRAC, 2002) and a new ADAPT model formulation was recommended. This new model differed from the previously used model in that some RV survey indices were excluded and population at age 10 for 1997-2001 was estimated rather than assumed equal to a value derived from averaging fishing mortalities.

Information presented in this report has been reviewed by the Transboundary Resource Assessment Committee at a meeting held in St. Andrews, N. B. in April 2002. Proceedings of that meeting (TRAC, 2002) and the resulting Stock Status Report (DFO, 2002) are available for reference.

The Fishery

Canadian landings of Georges Bank cod peaked at about 18,000 t in 1982 and have declined from about 14,000 t in 1990 to 1,100 t in 1995, reflecting the lower TAC (Table 1, Figure 2). The 2000 Canadian Georges Bank cod fishery was limited to a Canadian allocation of 1,600t, a decrease from the 1,800t allocation in 1999, but increased to 2100t for the 2001 season. The 2001 fishery opened in June. Catch by gear sector in the Canadian fishery (Figure 2) shows a consistent pattern in recent years. The 2001 Canadian Management Plan allocations by fleet sector and reported landings (from 2001 Quota reports) are shown below:

Fleet Sector	Allocation	Landings	Percent of Allocation
Fixed <65’	1369	1376	101
Mobile <65’	599	614	103
Fixed 65-100’	19	44	232
Mobile 65-100’	41	39	95
Vessels >100’	73	70	96
Total	**2101**	**2143**	**102**

Between 1978-2001, USA landings reached 11,000 t in 1984, then were stable at about 6,000 t until 1993 when Closed Area II was implemented. Landings ranged from 560t to 1,230t between 1994-1999, were 1,150t in 1999 and decreased to 662t in 2000, about the recent average. The reported 2001 USA landings were 1,360 t, over double the 2000 catch and the highest since 1993. Almost 100 percent of USA catches in 5Zj,m are taken by otter trawl gear.

Combined USA and Canada landings for 1978-2001 are shown in Table 2 and Figure 3. Catches in 2001 increased by 57% over 2000 and were the highest since 1994. Canadian catches increased by 34% and USA landings by 106% between 2000 and 2001.

Length composition from samples of landings and catches obtained by commercial port samples and at-sea Observer sampling were used to estimate catch at length and age composition for the Canadian fishery. A summary of the number of length and age samples used to estimate catch-at-age is shown in Table 3, Figure 4a. The fishery was adequately sampled and about 18,000 length observations and 1,509 age determinations were available to construct the catch-at-age for 2001 (Table 4). Comparison of length distributions between the at-sea and on-shore samples showed no substantial differences or trends (Figure 4b). Starting in 2000, quarterly weight-length relationships derived from at-sea Observer sampling from 1995-2000 were applied to estimate the catch-at-age. Landings were regulated by 100% dockside monitoring. Mobile gear catches by tonnage class group were derived to account for potential differences between large offshore trawlers and tonnage classes 2 and 3 trawlers in areas fished and size composition.

Precision estimates of intra-reader age determinations by the Canadian age reader were completed and results were acceptable with a CV of 2.37 and overall agreement of about 84 percent. A Canada/USA otolith exchange was completed and resulted in an overall agreement of about 87 percent with a CV of 2.09 (Table 5). Canadian intra-reader and the Canada/USA inter-reader exchange age comparisons were made with otoliths from the Canadian 2000 commercial fishery, the 2001 DFO RV survey and the NMFS 2000 spring survey. Consultation between the Canadian and USA age readers took place in Woods Hole, Mass., USA, during the 2002 TRAC benchmark review meetings. A total of 27 otoliths (disagreements from the 2001 aging exchanges) were re-aged by both readers using a dual microscope. For 60% of the differences, the USA ager agreed with the Canadian age. In the majority of cases, the differences showed the previous reading was under-aged and the USA ager noted missing an annulus reading the dorsal edge. The Canadian ager agreed with the USA age for 40% of the differences and the majority of cases were under-aging from the previous age. The Canadian ager noted missing a weak, close or poor annulus. Differences appeared across all age groups. A checky, close or weak 3rd annulus frequently caused a difference in interpretation for both agers.

Catch-at-age for the reported USA landings in 1994-2001 were estimated from USA length samples. For 2000 and 2001, USA length samples from the total 5Ze were considered to be representative of 5Zj,m landings (L. O'Brien, NEFSC, pers.comm.). USA ages for landings in 5Zj,m were limited and were therefore supplemented with Canadian age samples (Table 3).

Total removals-at-age and percent-at-age are given in Table 6 and in Figure 5. Average fishery weight-at-age and average beginning-of-year weights are given in Table 7. Fishery weight at length was used for estimating catch at age. Calculations of the population biomass were made using weights-at-age obtained from Canadian spring survey data (Hunt and Johnson, 1999). A length/weight relationship derived from 1986-99 surveys was used to calculate mean weight from mean length in each survey year. The data collected during surveys most adequately represents a sample of the entire population, while fishery data represents that portion of the population available to commercial gear, that is, the larger fish of the partially recruited ages.

Comparisons between observed catch-at-age and projected catch-at-age from the 2001 assessment are shown in Figure 6, and indicate considerable divergence in the contribution of the 1998 and 1995 year-classes at ages 3 and 6. In 2001, the 1998 year-class accounted for almost 36 percent of the catch in numbers, a higher proportion than the projected level of 15 percent. The 1995 year-class accounted for less than 10 percent of the catch compared to the projected level of 20 percent. Catch-at-length and age contributions for 2001 are shown in Figure 7 and indicate considerable overlap in length for adjacent agegroups. However, both inter and intra-reader age comparisons show an acceptable level of precision and no evidence of bias over the age range (Table 5). Comparison of the 2001 percent catch at age with the short term and long term average is shown in Figure 8 and shows a increase in the contribution of ages 5+ in 2001 over the long-term average.

DFO survey weight-at-age shows a declining trend but have been generally variable and without trend in recent years (Table 7, Figure 9). However, values from the 2002 survey were the lowest observed for some agegroups and use of these values will have an impact on the determination of population biomass for 2002 and the projected 2003 biomass.

Indices of Abundance

Research Surveys

Hunt (1990) describes the approach used to estimate mean catch per tow specific to the 5Zj,m area for Canadian and USA surveys. Only sets within the 5Zj,m area were used, with stratum areas adjusted to conform to the 5Zj,m boundary. Vessel and gear conversion factors, reported by Serchuk *et al*. 1994, were used to adjust results of the USA surveys conducted by the RV *Delaware II* to RV *Albatross IV* equivalents and to account for a change in trawl doors in 1985. The impact of vessel conversion factors was reported by Hunt and Buzeta (1996). The Canadian survey was initiated in 1986, while the USA surveys started prior to 1978.

The USA spring survey has used two different bottom trawls over the 1978-99 time period. The Yankee #41 trawl was used between 1978 and 1981, and the Yankee #36 trawl has been used since 1982. No conversion factors are available to account for potential differences in catchability between trawls and therefore the two series were considered as separate indices in the ADAPT model.

Catch in numbers and weight for the 2001 and 2002 DFO survey showed a decrease from that observed in 2000. The highest catch rates occurred in the Canadian zone in the 5Zj area along the northern edge. The 2002 catch distribution pattern (shown as box symbols in Figure 10) was similar to the average (shown as density contours in Figure 9), however DFO stratum 5Z2 accounts for most of the survey biomass. A substantial reduction in the contribution of DFO stratum 5Z3 (NW part of the Bank in the USA zone) between 2000 and 2002 is apparent (Figure 11). Single large sets of over 2t of cod have had a strong influence on the average catch per tow in both 2001 and 2002 and have reduced the magnitude of the decline between 2000 and 2001.

Results of analysis for each of the surveys are given in Table 8 and Figure 12.

The research vessel surveys were assigned a decimal year value (DFO=0.16, NMFS spring 0.29, NMFS fall 0.69) to correspond to the season in which the survey was conducted. This

eliminated the requirement to lag the NMFS fall survey as an index of beginning of year abundance for use in the ADAPT formulation.

The three survey indices for ages 3+ biomass, adjusted by the estimated catchability (Q's) at age from recent ADAPT formulations (Gavaris, 1988) are shown in Figure 12 (the 1982 NMFS spring survey is not shown due to scaling). In general, all three surveys appear to track year-class strength and provide a consistent index. The DFO surveys show a decline between 1990 and 1995, a substantial increase in 1996, a decline in 1997 and 1998, followed by an increase in 1999, a further increase in 2000 and a decrease in 2001 with a slight recovery in 2002. The 1994 NMFS fall survey catch per tow has a slight increase from 1993, then has remained at a low, stable level. The 1994 NMFS spring survey was the lowest observed, but increased in 1995 to the recent average level and remained stable. The most recent NMFS spring and fall surveys and the DFO spring survey remain at low levels.

Estimates of recruitment at age two from the surveys are shown in Figure 13 as population numbers derived from catch per tow, adjusted by catchability factors. The index of recruitment of the 1996 year-class is similar to the 1990 year-class. Overall, recruitment remains well below the average and appears to be very low for the 1997 and subsequent year-classes.

Commercial Fishery Catch Rates

The mobile gear catch rate was used as an index of abundance in the 1995 evaluation of stock status. However, the reduced TAC and bycatch limitations imposed since 1995 and the change from a directed to a bycatch fishery preclude use of catch rates as an indicator of abundance. Effort information for the longline fleet was not collected in 1994 and therefore catch rates for this fleet sector in 1994 are not available.

A summary of catch, effort and catch per day for the mobile, longline and gillnet fleets for 1990-2001 is given in Table 9. No standardization to account for possible tonnage class differences was applied and only trips landing more than 500kg of cod were included. Estimated total effort (number of fishing days) is calculated from the catch per day and reported catch to account for missing effort data for some trips. For example, only 30% of longline vessels reported effort in 1990, representing 825 fishing days with an average catch of 1.91 t per day. This catch per day was divided into the total reported catch to estimate total fishing days (5202/1.91 = 2724 days). The number of active vessels and total effort in 1995 were less than 50% of the 1990-94 average for all three fleet sectors.

The number of Canadian vessels, by gear sector, with cod landings of greater than 500kg per trip for the 1990-2001 time period are shown in Figure 14. Overall, the number of vessels participating in the fishery declined between 1990 and 1995 with an increase in again 1996. Most of this increase was due to the addition of about 20 tonnage class one longline vessels in 1996. The number of vessels has remained relatively stable since 1996 with a slight increase in 2001.

Landings per day fished declined for all three gear sectors but has remained relatively constant between 1998 and 2001 (Figure 15). Generally, catch rates are higher for the fixed gear sector compared to the mobile gear sector.

Effort distribution for the Canadian mobile and longline gears, with landings >500 t, in the 5Ze+4Xp area is shown in Figure 16 for 2001 and for the 1999-2000 time periods. Effort distribution of the mobile gear appears to have been stable. For longline gear, an increase in 2001 effort in the areas adjacent to the 5Ze boundary is apparent.

Fishers continue to report difficulty in avoiding areas of cod abundance. Substantial changes to fishing practices have been required to ensure that cod allocations are not overrun in advance of taking haddock allocations.

Longline Research Survey

A longline research survey of the Georges Bank area was initiated in 1995 using a box design with one set in each selected box. A detailed description of methods, results and comparison of the annual results with Sequential Population Analysis (SPA) population estimates is reported in Johnston and Hunt (1999) and by Hunt and Hatt (2001). Preliminary results for 1996-2001 standardised catch in weight and numbers is shown in Figure 17. An increase in abundance and biomass is evident from 1999 to 2001. Utility of the survey as an indicator of changes in stock abundance was considered at the benchmark review (TRAC, 2002). It was concluded that the trend from the survey showed consistency with population trends but that the uncertainties associated with conformity to the experimental design and the limited spatial coverage of the survey precluded it's use as an index within the ADAPT formulation. The survey may provide some supplemental information if it continues to be conducted in the future but it is considered to have limited analytical merit.

Partial Recruitment to the Fishery

Hunt and Johnson (1999) derived estimates of partial recruitment to the fishery by gear type for the period 1988-98. They indicate that partial recruitment at ages three and less has declined in the recent part of the time series. Further investigation of partial recruitment was completed in the benchmark review (TRAC, 2002). Three options for estimating fishing mortality or population size at the oldest age were considered.

1. F_{10} = weighted mean of F_{8-9} for 1978 – 1999; all ages estimated in 2000
2. Imposed flat-topped PR (4-10) in 2000; 4 – 6 estimated & 7 – 10 calculated
3. Estimation of N10 in 1997-2001 with F_{10}= weighted mean for F_{8-9} 1978 - 1996

Partial recruitment patterns and trends in RV q were used to evaluate the merits of each option. The first option produced a dome PR for 1999 and 2000 but an unrealistic pattern for 1995-1999 and RV q's that increased monotonically. The second option also had an unrealistic PR for 1999 and 1994-1998 but a more asymptotic pattern in RV q's. The third option gave results that seemed more consistent with fishery trends and an asymptotic pattern in RV q's (Figure 18).

Cod distribution in relation to Canadian and USA fleet distributions could have caused decline in exploitation of large cod. Prior to 1994, about 50% of the annual catch of age 7+ were caught during the first quarter winter fishery. The fishery caught large spawners and after spawning, cod move into deeper water. Since 1994, the Canadian fishery has been closed until June 1st which is consistent with a reduction in availability of large cod. At about the same time the USA introduced closure of Area II. Also, to avoid overruns of limiting cod

allocations while directing for haddock, the Canadian fishery avoids areas of cod abundance. This is consistent with what fishermen have been reporting as well as observations that large cod are not in commercial aggregations after spawning, making it uneconomic to direct for them.

Spawning Stock Biomass (SSB) Calculation

Results of a study reported by Hunt (1995) were updated with more recent DFO spring survey data to estimate the proportion of cod mature at age for the period 1986-2002. A three-year average was applied to the annual estimates with the years 1978-85 set to the 1986 value. Results are shown in Table 10 and show an increase from about 30-40% mature at age 2 prior to the mid-1980's to 40-60% in the mid-1990's and over 70% in the latter part of the series. Spawning stock biomass (SSB) was estimated by applying the proportion mature at age and beginning of year mean weight at age to the population abundance estimate derived from ADAPT.

Further evaluation of changes in the age at first maturity is required including small sample size and the consistency of maturity assignments. For the purpose of describing trends in adult stock biomass, the biomass associated with ages 3+ is considered to be more representative and less influenced by interannual variations in mature individuals.

Estimation of Stock Parameters

The adaptive framework (Gavaris 1988) was used to calibrate the Sequential Population Analysis with the three research survey age-specific indices of abundance. The integrated formulation used the following data:

$C_{a,y}$ = catch
a=1 to 10, y=1978 to 2001

$I_{1,a,y}$ = USA fall survey
a=1 to 6 y=1978.69 to 2001.69
$I_{2,a,y}$ = USA spring survey (Yankee #41 trawl)
a=1 to 8, y=1978.29 to 1981.29

$I_{3,a,y}$ = USA spring survey (Yankee #36 trawl)
a=1 to 8, y=1982.29 to 2001.29

$I_{4,a,y}$= Canadian spring survey
a=2 to 7, y=1986.16 to 2002.16

$\theta_{a,t'} = \ln \text{population abundance}$ for ages *a* = 2, 3 ... 10 at time $t' =$ 2002
$\kappa_{s,a} = \ln \text{calibration constants}$ for each abundance index source *s*, and ages, *a*.

A solution for the parameters was obtained by minimizing the sum of squared differences between the natural logarithm observed abundance indices and the natural logarithm population abundance adjusted for catchability by the calibration constants. The objective function for minimization was defined as

$$\underset{s,a,t}{\Psi}\left(\hat{\theta},\hat{\kappa}\right)=\sum_{s,a,t}\left(\psi_{s,a,t}\left(\hat{\theta},\hat{\kappa}\right)\right)^2=\sum_{s,a,t}\left(\ln I_{s,a,t}-\left(\hat{\kappa}_{s,a}+\ln N_{a,t}\left(\hat{\theta}\right)\right)\right)^2$$

For convenience, the population abundance $N_{a,t}\left(\hat{\theta}\right)$ is abbreviated by $N_{a,t}$. At time t', the population abundance was obtained directly from the parameter estimates, $N_{a,t'}=e^{\hat{\theta}_{a,t'}}$. For all other times, the population abundance was computed using the virtual population analysis algorithm, which incorporates the common exponential decay model $N_{a+\Delta t,t+\Delta t}=N_{a,t}e^{-\left(F_{a,t}+M_a\right)\Delta t}$.

Partitioning of the USA spring survey was introduced in 1998 to account for a change in the survey trawl in 1982. Experimentally derived conversion factors between the two trawl types for cod are not available and further investigation of trawl gear and vessel effects may be required.

The survey indices were compared to beginning of year population abundance. Natural mortality was assumed constant and equal to 0.2 for all age groups. The fishing mortality rate on age 10 for 1997-2001 was estimated from the SPA model. The fishing mortality rate on age 10 for 1978-1996 was calculated as the weighed average for ages 8 to 9 in the same year. Errors in the catch-at-age were assumed negligible relative to those for the abundance index. The errors for the log transformed abundance index were assumed independent and identically distributed.

ADAPT was used to solve for the parameters using the techniques described by Gavaris (1988) and Hunt and Johnson (1999). Parameter estimates and associated precision were derived using a bootstrap statistical technique.

Initial trial ADAPT formulations which included age one in 2002 did not result in statistically significant estimates at this age and therefore the 2001 year-class in 2002 was set to an arbitrary low value of 1.5 million.

The ADAPT formulation used in this assessment is a modification of the model used in 2001. In particular, RV indices for ages 1 and 8 in the DFO survey and age 0 in the NMFS fall survey were excluded. The apparent lack of proportionality with stock abundance and frequent zero catches for these three indices were the basis for their exclusion. The previous assessment estimated F_{oldest} as the average on ages 5-9. Given the dome-shaped partial recruitment noted above, it was considered more appropriate to use the population weighted average on ages 8-9 for F_{oldest} and to estimated F_{10} directly for 1997-2000.

Assessment Results

Parameter estimates, bias adjustment and population estimates derived from the above ADAPT formulation are given in Table 11. Population parameter estimates for 2002 have a relative error of 29% to 37% for ages 3 to 10, an improvement from those seen in the 2001 ADAPT-based analytical assessment. However, the parameter estimate for age 2 in 2002 has a high standard error. Relative error for estimates at age 10 in 1997-2000 ranged from 41 to 59%. In general, catchabilities for survey indices show a flat topped selection at ages 4 and older. Catchabilities were highest for the DFO spring survey, followed by the NMFS spring surveys and the NMFS fall survey.

There appear to be some year effects in the residuals for survey indices (Figure 19). However, residuals by age for all three surveys appear to be reasonably well balanced and without trend within cohorts. The relatively high number of positive residuals for NMFS surveys prior to 1985 may be a function of trawl door conversion factors. As noted above, preliminary analysis of the impact of trawl door conversion has been completed but further work is required before alternative conversion factors can be recommended.

The decline in adult stock biomass (ages 3+) between 1990 and 1995 was substantial, and the biomass was the lowest observed in 1995 at 8,900 t (Figure 20, Table 12). However, the biomass shows a gradual increase from 1995 to about 21,100 t in 2001. A decrease in biomass occurred in 2001 and in 2002 and is estimated to be about 17,300 t in 2002. Much of this decrease is associated with the low weight-at-age from the 2002 DFO survey. About 30% of the 2002 biomass is comprised of ages 8-10 and biomass remains well below the long term average of over 30,000 t.

Given the dome-shaped partial recruitment pattern described above, fishing mortality on ages 4-6 is considered to be representative of average exploitation rate. Exploitation (Table 12) increased rapidly between 1989 and 1991 and was over three times the $F_{0.1}$ = 0.2 reference level in 1991-93. The decline that began in 1994 is consistent with reduced effort. Fishing mortalities since 1995 have been close to the $F_{0.1}$ reference level. The rate of exploitation for the stock has been over 30% for most of the time series, above 50% in 1991-94, and close to the $F_{0.1}$ reference level of about 16% since 1998 (Figure 21).

The reduced exploitation starting in 1995 has resulted in improved survival of the 1992 and 1995 year-classes and increased the relative contribution of ages 5 and older (Figure 22). The higher mean weight-at-age and survival associated with these older fish has generated most of the increased stock biomass but reflects growth rather than recruitment.

Recruitment since the 1990 year-class has been below average. The 1992, 1995 and 1996 year-classes show some improvement to above the recent average recruitment. The 1998 year-class is below the recent average and indications for subsequent year-classes show very poor recruitment prospects (Figure 21 and Table 12).

Comparison of results of this assessment with those derived using the ADAPT formulation of 2001 is given in Figure 23. The two results have very similar trends in abundance and exploitation rates but the current formulation indicates a somewhat higher SSB since 1994 and lower exploitation rates in the early 1990's and recent years. Recruitment estimates are essentially the same for both formulations.

Retrospective Analysis

Typically, if present, a retrospective pattern results in overly optimistic estimates for a year-class in the first year with a decline as additional data are added to the model. Similarily, fishing mortality increases as more data are added. Results of the analysis (Figure 24) confirm a pattern for fishing mortality in the mid-1990's to be under-estimated and abundance over-estimated relative to current estimates. A reverse trend to under-estimate initial year-class size is evident for abundance at age one and is most pronounced for the 1999 year-class.

The retrospective pattern seen in this assessment is much less pronounced than that seen in the the 2001 assessment results (Hunt and Hatt, 2001).

Yield Per Recruit Analysis

Hunt and Johnson (1999) reported on a yield per recruit analysis using average mean weight-at-ages 1-15 and partial recruitment reflecting the recent 1995-98 trend in the fishery. Results indicated an $F_{0.1}$ fishing mortality of 0.199 and confirm the value of 0.2 used in previous assessments.

Prognosis

Catch projections were completed using the bias-adjusted beginning of year population abundance for 2002 derived from ADAPT. Partial recruitment was derived from the 1999-2001 fishing mortality matrix (Table 12), to reflect changes in PR associated with both gear and season. Mean (1999-2001 fishery) and beginning of year (2000-2002 RV survey) weights-at-age were used to reflect the recent trend in weight-at-age. Recruitment for 2001 and 2002 age one was set to 1.5 million (Table 13).

Yield projection at $F_{0.1}$ for 2002 indicates a **combined** Canada/USA yield of about 1,900 t. Details of the projection are given in Table 13 and Figure 25. There is about a 20% relative error associated with the projected catch. At the $F_{0.1}$ yield, adult biomass will remain stable between 2002 and 2003. Only at 2002 yields of less than 1,000t is there a 50% or better chance of a 10% increase in biomass between 2002 and 2003 (Figure 26). The 1998 year-class-at-age 4 is expected to account for about 28% of the catch biomass in 2002. It is also important to note that small differences in the 2002 yield near the $F_{0.1}$ level substantially increase the chances of deviation from the reference level.

Adult biomass levels and subsequent **recruitment** abundance-at-age 1 are compared in Figure 27 for the 1978-2001 time period. Recruits appear to have a positive correlation with biomass and the probability of good recruitment increases at higher biomass levels. The projected 2002 adult biomass of 17,300 t is well below the stock size (>25,000t) at which improved recruitment would be expected to occur. Rebuilding to increase the adult biomass above the projected 2002 level would enhance the prospects for the future. The relationship between recruits and adult biomass (Figure 28) shows a decline since 1996 indicating poorer survivorship.

Gains in fishable biomass may be partitioned into those associated with somatic growth of cod which have previously recruited to the fishery and those associated with new recruitment to the fishery (Rivard 1980). Over the long term, about 60-90% of the total stock production (Figure 29) has been derived from growth and the rest has come from

recruitment. In recent years, due to weak recruitment, the amount due to growth has increased and is now over 90% of the total.

Yields from the fishery have exceeded surplus production in some years, particularily in the early 1990's. Low productivity in 2001 and the increase in 2001 catches resulted in yield greater than production (growth overfishing).

With the current poor recruitment and exploitation rates near the present levels, improvement in stock status is not expected in the near term.

Fishing by Canada and USA is limited to their respective territories. It is desirable to distribute effort across the management unit in relation to biomass patterns. The Transboundary Management Guidance Committee, a joint Canada and USA industry/government consultative body, made a proposal in December 2001 for a sharing formula that respects the biomass distribution across the maritime boundary and recognizes spatial structure. While the proposal would only take effect in 2003 if ratified, Canada may voluntarily adopt the sharing formula for 2002. For 2002, the sharing proposal grants Canada 73% of the cod TAC for 5Zj,m.

Cod and haddock are often caught together in the Canadian groundfish fisheries. However, their catchabilities to the fisheries differ and they are not necessarily caught in proportion to their relative abundance. Exploitation of haddock at $F_{0.1}$ levels with current fishing practices may compromise the achievement of rebuilding objectives for this cod stock. Anecdotal information from the 2001 fishery and prosecution of suspected violators suggest an increasing probability of cod discards and catch misreporting. There is a potential for this practice to increase in the 2002 fishery if the allowable cod catch is lowered while the haddock catch increases.

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Table 1. Nominal landings(t) of cod by year, gear and month for Canada in unit areas 5Zj,m for 1986-2001. (see Hunt and Hatt (2000) for 1978-1985 landings detail)

YEAR	GEAR	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Total**
1986	Gillnet						43.6	81.9	75.1	28.7				229.3
	Longline		58.1	81.0	12.0	24.2	146.4	127.2	635.1	619.0	408.6	12.1		2123.6
	Misc	0.5	2.0	8.6	15.3	10.3	3.1	0.3	0.8	0.2	0.5	0.3		41.7
	Mobile	14.4	8.8		15.1	6.1	2364.2	3137.6	476.8	49.2	10.8	4.4	21.7	6109.2
1986	Total	14.9	68.9	89.6	42.5	40.5	2557.3	3346.9	1187.8	697.1	419.9	16.8	21.7	8503.8
1987	Gillnet						109.3	248.5	308.5	38.2				704.6
	Longline		6.2	112.0	68.1	8.2	314.9	672.8	1110.2	796.5	310.0	12.5	32.7	3444.0
	Misc	4.7	10.9	14.9	16.6	9.2	10.8	6.3	3.7	1.1	1.5	6.3	1.9	87.9
	Mobile	18.7	0.5	3.3			2484.9	3940.8	889.5	145.0	2.1	78.3	44.3	7607.3
1987	Total	23.3	17.7	130.2	84.7	17.4	2919.9	4868.3	2311.9	980.8	313.6	97.1	78.9	11843.8
1988	Gillnet						180.1	224.4	140.6	49.7	20.9			615.8
	Longline	53.9	86.3	68.0	205.2	27.2	1277.5	1773.5	487.4	455.3	121.3	28.2	1.4	4585.1
	Misc	2.3	9.0	11.7	10.5	16.4	10.3	6.7	1.7		0.5	1.9	2.1	72.9
	Mobile	23.0	520.0	56.5		12.7	3146.9	3138.6	416.2	17.5	98.5	28.9	8.5	7467.4
1988	Total	79.2	615.3	136.2	215.7	56.2	4614.8	5143.2	1046.0	522.5	241.3	58.9	11.9	12741.2
1989	Gillnet						131.4	358.9	440.2	174.5	9.2			1114.2
	Longline	40.6	202.2	244.5	78.8	248.1	938.4	1130.0	1360.0	346.2	64.7			4653.5
	Misc	7.1	6.9	9.0	21.2	33.0	16.6	5.3	1.4	0.0	2.6	2.7		105.8
	Mobile	4.7	139.8	7.2		2.3	1587.8	86.5	70.0	1.7	87.2	32.7	1.6	2021.5
1989	Total	52.3	348.9	260.7	99.9	283.3	2674.2	1580.8	1871.6	522.5	163.7	35.4	1.6	7895.0
1990	Gillnet						113.5	343.9	309.3	142.7				909.3
	Longline	125.3	150.1	259.7		129.4	1196.4	1523.4	1154.4	642.6	244.1	13.0		5438.4
	Misc	6.2	12.6	19.2	19.0	9.9	22.0	1.6	1.2	1.3	0.7	0.5	1.5	95.8
	Mobile					1.3	3189.1	1755.4	1551.1	946.0	461.0	15.8	1.1	7920.8
1990	Total	131.5	162.6	278.9	19.0	140.6	4521.0	3624.3	3016.0	1732.6	705.8	29.4	2.6	14364.3
1991	Gillnet					17.2	433.8	749.3	355.4	164.4	20.5			1740.6
	Longline	49.3	334.9	190.3	230.0	201.9	630.1	1063.9	952.4	742.3	367.8	113.4	46.9	4923.1
	Misc	7.7	7.8	7.4	25.2	14.6	19.8	24.5	19.7	7.8	0.7	8.8	0.3	144.3
	Mobile	348.3	33.1	22.2	0.6		3456.0	1492.5	671.3	314.1	295.4	14.7	5.7	6653.8
1991	Total	405.2	375.9	219.9	255.8	233.6	4539.6	3330.2	1998.8	1228.6	684.4	136.8	52.9	13461.8
1992	Gillnet					0.7	293.6	350.1	341.9	202.8	25.7	2.1		1216.8
	Longline	114.2	339.6	476.7	280.4	240.7	931.3	747.5	653.6	522.5	338.7	106.2		4751.3
	Misc	9.4	13.4	19.2	21.4	22.8	10.4	6.1	4.8	2.3	3.0	0.6	0.4	114.2
	Mobile	266.2	328.8		0.6	3.9	2834.9	972.2	286.9	213.7	541.5	132.2	9.4	5590.4
1992	Total	389.8	681.8	495.9	302.4	268.2	4070.2	2076.0	1287.2	941.3	908.9	241.1	9.9	11672.6
1993	Gillnet						286.5	367.4	260.9	212.1	47.4			1174.3
	Longline	4.2	30.4	166.0	80.4	148.1	422.0	514.4	461.9	261.1	122.3	119.8	63.0	2393.6
	Misc	8.6	4.1	10.3	13.5	17.4	4.5	4.9	1.0	0.3	0.7	1.5		66.9
	Mobile	823.8	997.5	77.6	380.3		1204.3	590.5	162.5	123.4	237.3	177.8	113.8	4888.8
1993	Total	836.7	1032.0	253.9	474.2	165.5	1917.3	1477.2	886.3	596.8	407.6	299.2	176.8	8523.6
1994	Gillnet					0.1	133.4	539.3	243.0	96.9	18.5			1031.2
	Longline					0.1	409.1	481.2	868.8	492.3	4.6	30.3		2286.5
	Misc	7.0	6.6	10.1	14.3	8.6	7.0	3.6	1.6	0.7	1.6	3.4	1.0	65.5
	Mobile	2.0					777.1	410.2	115.3	127.5	263.3	116.7	82.3	1894.4
1994	Total	9.0	6.6	10.1	14.3	8.8	1326.6	1434.4	1228.8	717.3	288.0	150.4	83.4	5277.6

Table 1. Continued

YEAR	GEAR	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Total**
1995	Gillnet						17.3	39.4		69.7				126.4
	Longline						116.3	162.7	122.5	97.6	19.9	20.3	6.7	545.9
	Misc	1.6	3.7	4.3	4.6	4.4	4.6	7.7	2.9	0.6	0.1	0.0		34.6
	Mobile	1.0					100.2	62.1	56.9	82.3	25.3	41.1	24.4	393.4
1995	Total	2.6	3.7	4.3	4.6	4.4	238.4	271.9	182.3	250.2	45.3	61.4	31.2	1100.4
1996	Gillnet						25.8	137.5	81.3					244.5
	Longline						28.8	389.0	290.3	91.0	136.9	65.5	21.4	1023.0
	Mobile	2.2					217.2	96.3	99.9	57.8	42.2	40.0	103.2	658.8
1996	Total	2.2					271.7	622.8	471.5	148.8	179.1	105.5	124.6	1926.3
1997	Gillnet						132.6	132.8	107.4	50.6	46.9			470.3
	Longline						176.6	431.8	384.8	254.8	132.0	14.7	21.2	1415.9
	Mobile						360.4	165.9	210.4	134.9	55.9	52.0	53.0	1032.5
1997	Total						669.6	730.6	702.6	440.3	234.8	66.7	74.2	2918.7
1998	Gillnet						75.7	89.6	62.8	25.1	46.4			299.6
	Longline						74.0	344.5	220.8	196.7	87.3	21.2	18.2	962.8
	Mobile						177.9	70.5	138.3	94.6	98.6	38.6	26.5	645.1
1998	Total						327.7	504.6	422.0	316.4	232.3	59.8	44.7	1907.4
1999	Gillnet						58.5	100.0	48.2	14.7	36.0	6.5	5.8	269.6
	Longline						94.7	288.1	243.7	152.4	106.7	26.5	17.2	929.4
	Mobile	3.2					226.1	156.0	46.8	71.6	58.6	37.7	19.4	619.5
1999	Total	3.2					379.3	544.2	338.7	238.7	201.3	70.8	42.3	1818.5
2000	Gillnet						55.1	76.2	28.3	23.6	40.7	9.4	4.4	237.7
	Longline						40.7	190.8	177.2	221.6	137.5	15.3	16.4	799.4
	Mobile	0.0					101.5	140.3	81.6	73.0	69.5	38.3	30.4	534.5
2000	Total	0.0					197.3	407.3	287.1	318.1	247.7	62.9	51.2	1571.1
2001	Gillnet						36.6	75.3	40.8	60.1	42.7	21.0		283.6
	Longline						62.4	211.6	273.3	282.4	229.3	57.9	16.2	1133.2
	Mobile						159.6	84.3	58.2	103.5	133.5	110.7	70.8	720.6
2001	Total						258.6	371.2	379.3	446.0	405.6	189.7	86.9	2137.4

Table 2. Summary of total catches (t) by Canada and the USA in unit areas 5Zj,m for 1978-2001. Canadian values for 1986-1998 revised from previous reports.

YEAR	CANADA		USA	TOTAL	
		REVISED			REVISED
1978	8778		5502	14280	
1979	5978		6408	12386	
1980	8063		6418	14481	
1981	8499		8094	16593	
1982	17824		8565	26389	
1983	12130		8572	20702	
1984	5763		10551	16314	
1985	10443		6641	17084	
1986	8504	(8411)	5696	14200	(14107)
1987	11844	(11845)	4792	16636	(16637)
1988	12741	(12932)	7645	20386	(20577)
1989	7895	(8001)	6182	14077	(14183)
1990	14364	(14310)	6378	20742	(20688)
1991	13462	(13455)	6777	20239	(20232)
1992	11673	(11712)	5080	16753	(16792)
1993	8524	(8519)	4019	12543	(12538)
1994	5278	(5277)	1229	6507	(6505)
1995	1100		665	1765	
1996	1926	(1885)	773	2699	(2658)
1997	2919	(2898)	557	3476	(3455)
1998	1907	(1874)	795	2702	(2669)
1999	1818		1150	2968	
2000	1572		662	2234	
2001	2137		1361	3498	

Table 3. Canadian and USA 5Zj,m commercial landings samples for 1978-2001. At-sea observer samples are included in Canadian length samples since 1994.

	USA			**Canada**		
	Samples	Lengths	Ages	Samples	Lengths	Ages
1978	29	2047	385	29	7684	1308
79	21	1833	402	13	3991	656
1980	16	1258	286	10	2784	536
81	21	1615	456	17	4147	842
82	45	4111	778	17	4756	858
83	40	3775	903	15	3822	604
84	44	3891	1130	7	1889	385
85	23	2076	597	18	7644	1062
86	27	2145	644	19	5745	888
87	23	1865	525	33	9477	1288
88	37	3229	797	43	11709	1984
89	19	1572	251	32	8716	1561
1990	28	1989	287	40	9901	2012
91	23	1894	397	45	10873	1782
92	25	2048	445	48	10878	1906
93	29	2215	440	51	12158	2146
94	13	1323	260	104	25845	1268
95	-	-	-	36	11598	548
96	3	284	74	129	26663	879
97	2	210	55	118	31882	1244
98	-	-	-	139	26549	1720
99	-	-	-	84	24954	918
2000				107	20782	1436
2001		8135	284	108	18190	1509

Table 4. Summary of 2001 Canadian commercial and IOP samples used to estimate catch-at-age. USA catch-at-age for 1994-2001 was provided by the USA, and based on commercial landings samples prorated by market category.

GEAR	MONTH	CATCH (T) BY MONTH	#LEN	#AGES	CATCH (T) BY QUARTER
OTB+Misc	Jan				
	Feb				
	Mar				0
	Apr				
	May				
	Jun	160	3101	278	160
	Jul	84	1304	195	
	Aug	58	408	38	
	Sep	104	508	33	246
	Oct	133	1605	110	
	Nov	111	656	125	
	Dec	71	326	43	315
Total Canadian		721	7908	822	721
Total USA		1361			
Total		2082			
Longline	Jan				
	Feb				
	Mar				0
	Apr				
	May				
	Jun	62			62
	Jul	212	1766	90	
	Aug	273	2423	190	767
	Sep	282	1318		
	Oct	229	2287	133	
	Nov	58			
	Dec	16			303
Total		1133	7794	413	1133
Gillnet	Jan				
	Feb				
	Mar				0
	Apr				
	May				
	Jun	37	569	78	37
	Jul	75	291	49	
	Aug	48	681	111	
	Sep	60			183
	Oct	43	677	36	
	Nov	21	270		
	Dec				64
Total		284	2488	274	284
Age Keys	Q1				
	Q2		3670	356	259
	Q3		8699	706	1196
	Q4		5821	447	682
Total Canada		**2137**	**18190**	**1509**	**2137**
Total Canada + USA		**3498**	**8135**	**284**	

Table 5. Results of intra-reader (Canada vs. USA) aging comparisons.

Canadian exchange samples: NED2001003 RV Spring Survey (53); Commercial sample - Oct. - (48); Observer sample - July - (22)
US exchange sample: US0103200102 RV Spring Survey (97)

1st Age	2nd Age Can									
US	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Total**
1	3									3
2		16	3							19
3		1	51	2						54
4			3	34	4					41
5				3	53	1				57
6					4	21	1			26
7						1	5	3		9
8								3	1	4
9									1	1
Total	3	17	57	39	61	23	6	6	2	214

CV=2.09
87% Agreement

DIFF		
-1	**0**	**+1**
12	187	15

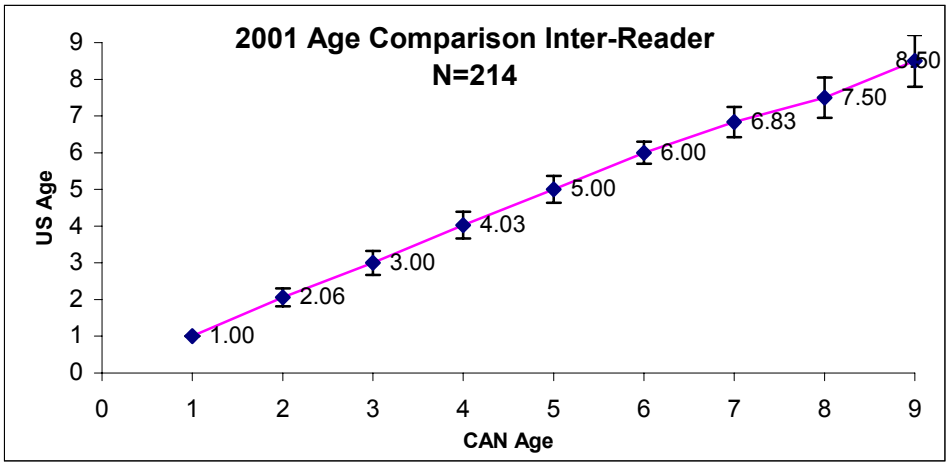

Figure . Inter-reader age comparison showing the average age and variance relative to the Canadian and USA age. For example, the average USA age for cod (aged as 4 by the Canadian ager) was 4.03.

Table 6. Catch-at-age (000's) and percent at age for combined Canada and USA fishery

Year	1	2	3	4	5	6	7	8	9	10	Total
(000's)											
1978	2	121	3588	1076	307	110	83	21	12	7	5327
1979	10	814	399	1774	545	149	22	45	4	3	3765
1980	1	987	1495	265	916	345	109	20	14	10	4162
1981	19	603	1443	1249	155	595	169	65	21	16	4335
1982	6	2682	1686	1429	1066	189	345	157	21	26	7607
1983	40	1319	3416	1474	466	283	31	71	12	3	7115
1984	10	269	911	1346	511	290	230	31	18	39	3655
1985	12	2792	1221	631	941	224	96	100	9	11	6037
1986	28	326	2188	513	304	400	58	39	9	3	3868
1987	14	3666	865	1099	144	121	167	37	15	6	6134
1988	10	320	3653	646	861	144	102	143	29	29	5937
1989	1	740	652	1837	193	314	56	25	37	18	3873
1990	7	678	3196	962	1195	116	122	10	14	30	6330
1991	11	626	783	1939	953	790	93	56	15	20	5286
1992	86	2358	1251	432	908	250	233	25	21	7	5571
1993	4	414	1967	809	215	332	110	93	17	15	3976
1994	2	182	486	751	246	41	59	26	16	6	1814
1995	0	56	235	120	89	14	4	3	1	2	525
1996	1	39	231	386	75	47	11	3	4	0	796
1997	3	107	155	287	291	70	32	10	4	1	960
1998	0	81	272	136	138	115	18	11	3	2	775
1999	2	46	422	271	80	44	41	9	0	3	919
2000	0	53	116	325	118	30	18	11	2	0	674
2001	0	2	15	405	196	355	92	28	16	5	1114
Percent											
1978	0.0	2.3	67.4	20.2	5.8	2.1	1.6	0.4	0.2	0.1	100.0
1979	0.3	21.6	10.6	47.1	14.5	4.0	0.6	1.2	0.1	0.1	100.0
1980	0.0	23.7	35.9	6.4	22.0	8.3	2.6	0.5	0.3	0.2	100.0
1981	0.4	13.9	33.3	28.8	3.6	13.7	3.9	1.5	0.5	0.4	100.0
1982	0.1	35.3	22.2	18.8	14.0	2.5	4.5	2.1	0.3	0.3	100.0
1983	0.6	18.5	48.0	20.7	6.5	4.0	0.4	1.0	0.2	0.0	100.0
1984	0.3	7.4	24.9	36.8	14.0	7.9	6.3	0.8	0.5	1.1	100.0
1985	0.2	46.2	20.2	10.5	15.6	3.7	1.6	1.7	0.1	0.2	100.0
1986	0.7	8.4	56.6	13.3	7.9	10.3	1.5	1.0	0.2	0.1	100.0
1987	0.2	59.8	14.1	17.9	2.3	2.0	2.7	0.6	0.2	0.1	100.0
1988	0.2	5.4	61.5	10.9	14.5	2.4	1.7	2.4	0.5	0.5	100.0
1989	0.0	19.1	16.8	47.4	5.0	8.1	1.4	0.6	1.0	0.5	100.0
1990	0.1	10.7	50.5	15.2	18.9	1.8	1.9	0.2	0.2	0.5	100.0
1991	0.2	11.8	14.8	36.7	18.0	14.9	1.8	1.1	0.3	0.4	100.0
1992	1.5	42.3	22.5	7.8	16.3	4.5	4.2	0.4	0.4	0.1	100.0
1993	0.1	10.4	49.5	20.3	5.4	8.4	2.8	2.3	0.4	0.4	100.0
1994	0.1	10.0	26.8	41.4	13.6	2.2	3.2	1.4	0.9	0.3	100.0
1995	0.0	10.6	44.8	22.9	17.0	2.7	0.8	0.6	0.2	0.4	100.0
1996	0.1	4.9	29.0	48.5	9.4	5.9	1.4	0.3	0.5	0.0	100.0
1997	0.3	11.2	16.2	29.8	30.3	7.3	3.4	1.0	0.4	0.1	100.0
1998	0.0	10.4	35.1	17.5	17.8	14.8	2.3	1.4	0.4	0.3	100.0
1999	0.2	5.1	46.0	29.5	8.7	4.8	4.4	1.0	0.0	0.3	100.0
2000	0.0	7.9	17.2	48.2	17.5	4.5	2.7	1.7	0.3	0.0	100.0
2001	0.1	1.4	36.4	17.6	31.8	8.3	2.5	1.4	0.4	0.0	100.0
Average											
78-90	0.2	20.9	35.5	22.6	11.1	5.4	2.4	1.1	0.3	0.3	100.0
97-01	0.1	7.2	30.2	28.5	21.2	7.9	3.1	1.3	0.3	0.1	100.0

Table 7. Weight-at-age (kg) derived from fishery (mid-year) and from 1987-2002 Canadian surveys (beginning of year) for 5Zj,m cod.

Midyear	0	1	2	3	4	5	6	7	8	9	10
1978	0.05	0.707	1.310	2.461	3.469	4.336	5.787	7.374	8.492	11.785	13.624
1979	0.05	0.889	1.494	2.149	4.211	4.888	7.178	9.183	10.313	11.699	14.064
1980	0.05	0.836	1.460	2.468	3.668	5.647	6.676	8.390	9.089	8.432	14.351
1981	0.05	0.882	1.495	2.358	3.415	5.213	7.222	8.565	9.888	14.170	13.574
1982	0.05	0.765	1.402	2.664	3.834	5.352	6.511	9.363	9.897	12.503	13.680
1983	0.05	0.971	1.490	2.377	3.309	4.637	6.393	7.964	10.286	11.227	12.209
1984	0.05	1.053	1.635	2.451	3.619	5.083	6.582	8.909	10.104	11.303	13.792
1985	0.05	0.907	1.418	2.086	3.887	5.087	6.412	8.097	10.236	11.418	12.724
1986	0.05	0.929	1.475	2.447	3.660	5.603	7.191	8.915	9.955	12.687	8.913
1987	0.05	0.726	1.481	2.495	4.187	5.810	7.726	8.949	10.013	11.414	13.928
1988	0.05	0.786	1.520	2.359	3.511	5.401	6.647	8.776	9.987	11.143	13.166
1989	0.05	0.809	1.617	2.269	3.772	5.396	6.694	8.222	10.718	11.665	14.143
1990	0.05	0.831	1.560	2.462	3.522	4.892	6.333	8.456	10.648	12.580	14.043
1991	0.05	1.114	1.627	2.548	3.420	4.769	5.891	7.410	10.520	9.686	14.521
1992	0.05	1.148	1.542	2.464	3.843	4.704	6.156	7.509	9.846	12.059	14.521
1993	0.05	0.883	1.571	2.308	3.079	4.496	5.729	7.075	8.884	9.699	10.858
1994	0.05	0.906	1.457	2.409	3.830	4.804	7.092	7.862	8.934	9.698	10.374
1995	0.05	0.900	1.489	2.507	3.723	5.224	6.522	11.055	10.118	10.383	14.521
1996	0.05	1.034	1.538	2.358	3.337	5.237	6.358	6.916	8.455	12.883	10.514
1997	0.05	0.978	1.498	2.232	3.339	4.254	5.797	8.048	8.330	11.870	14.521
1998	0.05	0.629	1.483	2.373	3.193	4.270	5.827	6.990	8.298	12.684	11.815
1999	0.05	0.796	1.554	2.286	3.527	4.164	6.310	6.775	8.043	12.153	13.536
2000	0.05	0.866	1.458	2.128	3.075	4.230	4.923	6.200	7.344	8.267	12.974
2001	0.05	0.880	1.488	2.334	2.998	4.053	5.122	5.081	8.019	9.224	14.812
78-01	0.050	0.884	1.503	2.375	3.559	4.898	6.378	8.004	9.434	11.276	13.132
97-01	0.050	0.830	1.496	2.271	3.226	4.194	5.596	6.619	8.007	10.840	13.532

Beginning	0	1	2	3	4	5	6	7	8	9	10
1978	0.05	0.109	0.720	1.641	2.797	4.251	6.188	7.644	9.436	11.457	13.443
1979	0.05	0.109	0.720	1.641	2.797	4.251	6.188	7.644	9.436	11.457	13.443
1980	0.05	0.109	0.720	1.641	2.797	4.251	6.188	7.644	9.436	11.457	13.443
1981	0.05	0.109	0.720	1.641	2.797	4.251	6.188	7.644	9.436	11.457	13.443
1982	0.05	0.109	0.720	1.641	2.797	4.251	6.188	7.644	9.436	11.457	13.443
1983	0.05	0.109	0.720	1.641	2.797	4.251	6.188	7.644	9.436	11.457	13.443
1984	0.05	0.109	0.720	1.641	2.797	4.251	6.188	7.644	9.436	11.457	13.443
1985	0.05	0.109	0.720	1.641	2.797	4.251	6.188	7.644	9.436	11.457	13.443
1986	0.05	0.131	0.908	1.830	3.192	5.244	5.730	7.529	9.500	11.517	13.443
1987	0.05	0.117	0.733	1.830	2.916	5.298	7.156	8.800	6.960	10.950	14.667
1988	0.05	0.120	0.626	1.775	3.542	5.247	6.942	8.900	9.114	12.357	14.075
1989	0.05	0.174	0.748	1.900	3.227	5.498	7.023	8.194	8.758	12.000	13.443
1990	0.05	0.156	0.743	1.775	2.926	4.340	6.299	8.876	10.300	13.733	14.116
1991	0.05	0.117	0.818	2.032	3.440	5.080	6.370	9.268	10.860	11.700	16.013
1992	0.05	0.108	0.812	2.058	3.364	4.688	6.512	7.331	9.475	12.899	13.443
1993	0.05	0.065	0.792	1.791	3.178	4.735	6.130	7.482	8.662	11.217	9.660
1994	0.05	0.064	0.677	1.367	2.561	3.492	7.696	7.696	8.849	9.598	13.443
1995	0.05	0.133	0.549	1.512	2.319	3.640	5.422	6.794	8.597	12.163	16.403
1996	0.05	0.062	0.764	1.428	2.636	4.607	6.610	6.620	12.869	12.628	13.833
1997	0.05	0.082	0.704	1.585	2.311	3.551	6.657	7.137	10.067	10.424	16.532
1998	0.05	0.078	0.618	1.347	2.365	3.271	4.640	5.672	8.509	8.283	8.253
1999	0.05	0.120	0.802	1.337	2.270	3.076	4.828	7.497	11.335	8.881	13.443
2000	0.05	0.126	0.736	1.533	2.504	3.688	5.510	7.571	9.644	14.253	13.890
2001	0.05	0.109	0.684	1.348	2.398	3.548	5.024	6.829	7.540	10.770	10.433
2002	0.05	0.110	0.423	1.175	2.306	3.592	4.412	5.952	8.436	10.001	11.842
1986-2002	0.050	0.110	0.714	1.625	2.792	4.270	6.056	7.538	9.381	11.375	13.349
1997-2002	0.050	0.104	0.661	1.387	2.359	3.454	5.178	6.776	9.255	10.435	12.399

Table 8. Survey indices of abundance (catch per standard tow in numbers) adjusted for vessel and door conversions.

Spring DFO	1	2	3	4	5	6	7	8
1986	1.78	8.19	7.41	0.77	1.6	1.03	0.51	0.08
1987	0.12	4.31	1.55	1.81	0.39	0.21	0.44	0.21
1988	0.36	1.08	12.85	1.36	2.02	0.23	0.19	0.43
1989	0.84	5.22	1.84	4.11	0.62	0.8	0.1	0.2
1990	0.25	1.91	8.36	4.7	10.6	1.29	2.63	0.35
1991	2.83	2.43	3.4	3.93	2.06	2.87	0.36	0.6
1992	0.11	4.93	2.94	0.99	1.55	1.09	0.72	0.22
1993	0.07	0.85	4.15	1.5	0.89	1.82	0.66	0.64
1994	0.03	1.51	1.66	3.1	1.15	0.44	0.88	0.2
1995	0.08	0.45	2.99	1.82	1.25	0.45	0.11	0.16
1996	0.22	0.49	4.2	10.44	3.45	2.49	1.07	0.26
1997	0.07	0.9	1.37	3.19	3.04	0.52	0.12	0.08
1998	0.01	1.42	2.04	0.79	0.77	0.58	0.14	0.07
1999	0.01	0.38	3.12	2.63	1.08	0.76	0.46	0.02
2000	0	1.02	3.12	11.96	5.19	2.48	1.23	0.76
2001	0.01	0.09	1.93	1.25	3.35	1.55	0.8	0.54
2002	0.00	0.28	1.15	5.05	1.67	3.09	1.10	0.45
Fall NMFS								
1978	2.64	0.26	5.1	0.73	0.11	0.27		
1979	2.96	2.93	0.21	2.71	0.44	0.11		
1980	1.43	0.76	1.21	0.05	0.35	0.44		
1981	4.24	2.19	1.69	0.48	0.02	0.35		
1982	1.05	1.29	0.08	0.12	0	0.02		
1983	0.12	0.42	0.89	0.05	0.03	0		
1984	2.84	0.14	1.03	1.68	0.05	0.03		
1985	0.39	1.8	0.3	0.03	0	0.05		
1986	5.2	0.11	0.35	0	0	0		
1987	0.24	1.53	0.23	0.19	0	0		
1988	1.02	0.33	2.13	0.25	0.44	0		
1989	0.72	1.68	0.28	0.77	0.1	0.44		
1990	0.72	0.79	1.49	0.21	0.37	0.1		
1991	0.36	0.13	0.16	0.02	0.06	0.37		
1992	0.37	1.31	0.28	0	0.07	0.06		
1993	0.14	0.19	0.28	0.03	0	0.07		
1994	0.14	0.54	0.39	0.28	0.14	0		
1995	0.05	0.22	0.54	0.12	0.05	0.14		
1996	0.56	0.15	0.56	0.41	0.1	0.05		
1997	0.29	0.7	0.32	0.1	0.15	0.1		
1998	0.32	1.29	0.9	0.12	0.2	0.15		
1999	0.03	0.03	0.45	0.22	0.06	0.2		
2000	0.1	0.37	0.12	0.16	0.08	0.06		
2001	0.13	0.34	0.36	0.07	0.09	0.09		
Spring NMFS Yankee 41								
1978	0.27	0	5.1	1.12	1.61	0.34	1.37	0.19
1979	0.69	2.65	0.22	2.57	1	0.34	0.17	0.22
1980	0.03	2.96	2.9	0.28	3.01	0.59	0.12	0.08
1981	1.7	1.57	2.43	1.73	0.07	0.6	0.31	0.12
Spring NMFS Yankee 36								
1982	0.79	11.58	24.99	22.29	16.98	0	5.55	1.24
1983	0.69	3.63	6.33	1.36	1.06	0.66	0.28	0.11
1984	0.2	0.22	0.81	1.22	0.48	0.39	0.34	0
1985	0.08	3.67	1.15	1.92	2.75	0.6	0.35	0.45
1986	1.13	0.62	2.05	0.55	0.78	0.98	0.05	0.21
1987	0	2.17	0.46	0.98	0	0.34	0.28	0.06
1988	0.58	0.45	5.05	0.5	0.84	0.08	0.03	0.14
1989	0.21	1.55	0.47	2.39	0.46	0.54	0.07	0.06
1990	0.13	0.62	3.14	1.09	1.18	0.29	0.3	0.03
1991	1.31	1.12	0.92	1.63	0.83	0.69	0.08	0.03
1992	0.14	1.2	0.65	0.17	0.45	0.27	0.29	0.05
1993	0	0.83	2.32	0.47	0.08	0.33	0.08	0.08
1994	0.1	0.37	0.29	0.36	0.09	0.02	0.06	0
1995	0.09	0.52	1.64	0.88	1.63	0.35	0.47	0.06
1996	0.25	0.54	1.78	2.41	0.22	0.17	0.05	0
1997	0.1	0.37	0.11	0.73	0.93	0.1	0.23	0.1
1998	0	1.99	3.8	1.91	1.88	1.17	0.06	0.06
1999	0.04	0.24	1.24	1.14	0.66	0.31	0.18	0.06
2000	0	0.55	1.16	2.43	0.89	0.25	0.09	0.04
2001	0.00	0.12	1.60	0.17	0.63	0.20	0.00	0.02

Table 9. Summary of Canadian catch (t) and effort data (days) by gear sector for Georges Bank cod (value in brackets for effort is the calculated value from total landings divided by average landings per day).

	Mobile	Gillnet	Longline
1990 Total catch (t)	7854	910	5202
Total with effort (t)	7285	534	1579
Number of Boats	176	14	103
Percent with effort	92.7	58.7	30.4
Effort (fish_days)	3837(4133)	215(367)	825(2724)
Catch per day	1.9	2.48	1.91
1991 Total catch (t)	6698	1688	4706
Total with effort (t)	6395	1084	1581
Number of boats	188	26	118
Percent with effort	95.5	64.2	33.6
Effort (fish_days)	3769(3940)	308(480)	849(2530)
Landings per day	1.7	3.52	1.86
1992 Total catch (t)	5638	1217	4474
Total with effort (t)	5583	684	1893
Number of boats	138	19	130
Percent with effort	99	56.2	42.3
Effort (fish_days)	2051(2073)	389(691)	1076(2542)
Landings per day	2.72	1.76	1.76
1993 Total catch (t)	4890	1175	2387
Total with effort (t)	4877	943	1179
Number of boats	125	20	135
Percent with effort	99.7	80.3	49.4
Effort (fish_days)	2377(2385)	635(789)	1377(2776)
Landings per day	2.05	1.49	0.86
1994 Total catch (t)	1893	1031	2287
Total with effort (t)	1886	79	73
Number of boats	95	21	78
Percent with effort	99.6	7.7	3.2
Effort (fish_days)	1926(1932)	-	-
Landings per day	0.98	-	-
1995 Total catch (t)	313	123	505
Total with effort (t)	313	116	494
Number of boats	64	11	49
Percent with effort	99.9	94.3	97.8
Effort (fish_days)	506(506)	202(216)	522(532)
Landings per day	0.62	0.57	0.95

	Mobile	Gillnet	Longline
1996 Total catch (t)	656	245	984
Total with effort (t)	656	245	984
Number of boats	76	10	102
Percent with effort	100	100	100
Effort (fish_days)	1082	111	852
Landings per day	0.61	2.21	1.15
1997 Total catch (t)	1032	470	1394
Total with effort (t)	1009	409	1152
Number of boats	74	9	74
Percent with effort	97.8	87	82.6
Effort (fish_days)	1159(1186)	164(188)	708(860)
Landings per day	0.87	2.49	1.62
1998 Total catch (t)	640	299	928
Total with effort (t)	626	299	861
Number of boats	71	9	64
Percent with effort	97.8	100	92.8
Effort (fish_days)	1028(1051)	180	578(623)
Landings per day	0.61	1.66	1.49
1999 Total catch (t)	607	264	912
Total with effort (t)	607	264	912
Number of boats	69	7	60
Percent with effort	100	100	100
Effort (fish_days)	915	175	584
Landings per day	0.66	1.51	1.56
2000 Total catch (t)	523	238	794
Total with effort (t)	523	238	794
Number of boats	73	9	57
Percent with effort	100	100	100
Effort (fish_days)	1075	185	601
Landings per day	0.49	1.29	1.32
2001 Total catch (t)	710	284	1061
Total with effort (t)	710	284	1061
Number of boats	75	7	77
Percent with effort	100	100	100
Effort (fish_days)	1581	132	778
Landings per day	0.45	2.15	1.36

Table 10. Proportion mature at age for 5Zj,m cod from DFO research survey (see Hunt (1995)), and the three year mean.

	Age									
Year	1	2	3	4	5	6	7	8	9	10
1978	0.024	0.372	0.916	0.991	0.999	1.000	1.000	1.000	1.000	1.000
1979	0.024	0.372	0.916	0.991	0.999	1.000	1.000	1.000	1.000	1.000
1980	0.024	0.372	0.916	0.991	0.999	1.000	1.000	1.000	1.000	1.000
1981	0.024	0.372	0.916	0.991	0.999	1.000	1.000	1.000	1.000	1.000
1982	0.024	0.372	0.916	0.991	0.999	1.000	1.000	1.000	1.000	1.000
1983	0.024	0.372	0.916	0.991	0.999	1.000	1.000	1.000	1.000	1.000
1984	0.024	0.372	0.916	0.991	0.999	1.000	1.000	1.000	1.000	1.000
1985	0.024	0.372	0.916	0.991	0.999	1.000	1.000	1.000	1.000	1.000
1986	0.024	0.372	0.916	0.991	0.999	1.000	1.000	1.000	1.000	1.000
1987	0.044	0.264	0.735	0.956	0.994	0.999	1.000	1.000	1.000	1.000
1988	0.039	0.380	0.902	0.993	1.000	1.000	1.000	1.000	1.000	1.000
1989	0.003	0.255	0.973	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1990	0.021	0.393	0.952	0.998	1.000	1.000	1.000	1.000	1.000	1.000
1991	0.020	0.363	0.942	0.998	1.000	1.000	1.000	1.000	1.000	1.000
1992	0.018	0.575	0.990	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1993	0.016	0.585	0.992	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1994	0.023	0.508	0.979	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1995	0.044	0.593	0.979	0.999	1.000	1.000	1.000	1.000	1.000	1.000
1996	0.035	0.332	0.871	0.989	0.999	1.000	1.000	1.000	1.000	1.000
1997	0.026	0.275	0.844	0.987	0.999	1.000	1.000	1.000	1.000	1.000
1998	0.042	0.526	0.965	0.999	1.000	1.000	1.000	1.000	1.000	1.000
1999	0.004	0.822	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2000	0.000	0.898	0.964	0.995	1.000	1.000	1.000	1.000	1.000	1.000
2001	0.000	0.980	0.984	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2002	0.000	0.365	0.944	0.992	1.000	1.000	1.000	1.000	1.000	1.000
1978/80	0.024	0.372	0.916	0.991	0.999	1.000	1.000	1.000	1.000	1.000
1981/83	0.024	0.372	0.916	0.991	0.999	1.000	1.000	1.000	1.000	1.000
1984/86	0.024	0.372	0.916	0.991	0.999	1.000	1.000	1.000	1.000	1.000
1987/89	0.029	0.299	0.870	0.983	0.998	1.000	1.000	1.000	1.000	1.000
1990/92	0.019	0.444	0.961	0.999	1.000	1.000	1.000	1.000	1.000	1.000
1993/95	0.028	0.562	0.983	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1996/98	0.034	0.378	0.893	0.992	0.999	1.000	1.000	1.000	1.000	1.000
1999/2002	0.001	0.766	0.973	0.997	1.000	1.000	1.000	1.000	1.000	1.000

Table11. Statistical properties of estimates for population abundance and survey calibration constants from Bootstrap parameter estimates for 5Zj,m cod estimated from ADAPT.

Parameter	Estimate	Standard Error	Relative Error	Bias
Abundance[1997 10]	50.583	30.009	0.593	5.810
Abundance[1998 10]	38.094	21.279	0.559	4.710
Abundance[1999 10]	76.921	34.594	0.450	6.322
Abundance[2000 10]	109.919	45.180	0.411	4.264
Abundance[2001 10]	69.579	30.766	0.442	5.681
Abundance[2002 2]	906.801	662.744	0.731	167.428
Abundance[2002 3]	645.256	240.886	0.373	33.419
Abundance[2002 4]	1054.228	393.599	0.373	60.022
Abundance[2002 5]	419.695	151.165	0.360	24.079
Abundance[2002 6]	964.693	322.203	0.334	46.305
Abundance[2002 7]	626.832	184.350	0.294	25.499
Abundance[2002 8]	237.448	75.586	0.318	9.654
Abundance[2002 9]	166.089	54.037	0.325	7.614
Abundance[2002 10]	153.568	62.176	0.405	9.565
DFO Age 2	0.000398	0.000084	0.210	0.000003
DFO Age 3	0.001253	0.000247	0.197	0.000025
DFO Age 4	0.001734	0.000358	0.206	0.000034
DFO Age 5	0.002238	0.000428	0.191	-0.000014
DFO Age 6	0.002221	0.000468	0.211	0.000016
DFO Age 7	0.002158	0.000442	0.205	0.000046
NMFS Fall Age 1	0.000109	0.000019	0.175	0.000001
NMFS Fall Age 2	0.000145	0.000024	0.162	-0.000001
NMFS Fall Age 3	0.000214	0.000036	0.169	0.000001
NMFS Fall Age 4	0.000131	0.000023	0.179	0.000002
NMFS Fall Age 5	0.000156	0.000031	0.198	0.000004
NMFS Y41 Spr Age 1	0.000029	0.000014	0.475	0.000002
NMFS Y41 Spr Age 2	0.000314	0.000171	0.547	0.000047
NMFS Y41 Spr Age 3	0.000391	0.000175	0.448	0.000028
NMFS Y41 Spr Age 4	0.000434	0.000178	0.410	0.000011
NMFS Y41 Spr Age 5	0.000682	0.000315	0.461	0.000071
NMFS Y41 Spr Age 6	0.000771	0.000337	0.437	0.000051
NMFS Y41 Spr Age 7	0.001246	0.000562	0.451	0.000092
NMFS Y41 Spr Age 8	0.001599	0.000756	0.473	0.000188
NMFS Y36 Spr Age 1	0.000046	0.000010	0.206	0.000000
NMFS Y36 Spr Age 2	0.000234	0.000045	0.194	0.000002
NMFS Y36 Spr Age 3	0.000542	0.000096	0.177	0.000008
NMFS Y36 Spr Age 4	0.000704	0.000129	0.183	-0.000002
NMFS Y36 Spr Age 5	0.000895	0.000181	0.202	0.000017
NMFS Y36 Spr Age 6	0.000747	0.000154	0.206	0.000017
NMFS Y36 Spr Age 7	0.000852	0.000176	0.207	0.000027
NMFS Y36 Spr Age 8	0.000716	0.000159	0.222	0.000019

Table 12. Population estimates for 5Zj,m cod derived from ADAPT.

Abundance (000's)	Age 0	1	2	3	4	5	6	7	8	9	10	1+	3+
1978	11542	11051	2192	10494	3483	984	305	277	56	26	9	28869	15626
1979	11229	9449	9046	1685	5376	1887	531	151	152	27	11	28304	9809
1980	21128	9193	7727	6672	1021	2811	1055	301	104	84	19	28969	12048
1981	7654	17298	7526	5437	4118	598	1480	555	148	67	39	37228	12404
1982	5580	6267	14145	5618	3156	2251	350	679	303	63	23	32832	12420
1983	16500	4569	5125	9168	3087	1307	892	119	249	108	19	24622	14928
1984	5532	13509	3704	3011	4447	1212	653	476	69	140	53	27221	10007
1985	25766	4529	11051	2790	1648	2433	535	275	185	29	50	23475	7895
1986	8545	21095	3697	6539	1193	784	1150	238	139	62	11	34898	10106
1987	16806	6996	17246	2731	3380	515	368	580	142	79	28	32038	7796
1988	4810	13759	5715	10823	1460	1782	293	193	325	83	43	34433	14959
1989	6910	3938	11256	4393	5616	624	697	112	68	140	32	26845	11650
1990	11021	5658	3224	8553	3014	2963	339	292	42	33	69	24119	15237
1991	3159	9023	4626	2028	4133	1603	1354	173	130	26	15	23096	9447
1992	4371	2587	7378	3223	959	1652	465	406	59	56	5	16786	6822
1993	2977	3579	2040	3930	1522	400	547	159	126	26	22	12328	6709
1994	2324	2437	2926	1298	1463	525	136	152	33	21	1	8992	3628
1995	4539	1903	1994	2232	627	528	210	75	72	4	0	7645	3748
1996	5883	3716	1558	1582	1615	405	352	159	57	56	2	9502	4228
1997	1853	4817	3042	1240	1084	970	263	245	120	45	45	11827	3968
1998	3101	1517	3941	2393	874	629	532	152	172	89	33	10299	4841
1999	1140	2539	1242	3153	1711	592	389	330	108	131	71	10196	6415
2000	1105	934	2078	975	2201	1157	413	279	234	80	106	8350	5339
2001	1832	905	764	1659	699	1511	836	309	211	181	64	7075	5406
2002	1500	1500	739	612	994	396	918	601	228	158	144	6147	3908

Beginning of year biomass	0	1	2	3	4	5	6	7	8	9	10	1+	3 +	SSB
1978	577	1333	1766	17836	9694	4136	1895	2025	518	358	141	39703	36604	35170
1979	561	1140	7288	2865	14961	7927	3299	1105	1418	364	176	40541	32113	34220
1980	1056	1109	6226	11340	2842	11810	6561	2198	967	1148	290	44490	37156	37907
1981	383	2086	6063	9241	11462	2513	9200	4055	1382	913	614	47530	39380	40277
1982	279	756	11396	9548	8782	9458	2179	4966	2816	864	358	51123	38971	41799
1983	825	551	4129	15581	8590	5492	5543	867	2314	1467	298	44832	40152	39523
1984	277	1629	2984	5118	12376	5091	4058	3481	645	1902	837	38120	33506	33671
1985	1288	546	8904	4742	4586	10222	3326	2012	1718	395	783	37235	27785	30221
1986	427	2544	2979	11114	3321	3295	7147	1738	1297	861	178	34474	28951	30716
1987	840	1058	14530	4614	9591	2989	3103	4733	1061	1070	433	43182	27594	30564
1988	241	1738	5110	20381	4383	8051	2034	1742	3204	1129	680	48451	41603	40592
1989	346	601	9056	7333	16110	2635	4594	857	551	1905	489	44130	34473	39555
1990	551	1151	2537	16216	9266	13575	2145	2430	402	499	1107	49329	45640	43941
1991	158	777	4026	3900	13147	6836	6905	1264	1251	353	229	38688	33885	40177
1992	219	362	5999	6357	2975	7231	2883	2888	505	972	114	30285	23924	27375
1993	149	289	1909	7404	4697	1917	3292	1107	956	311	286	22168	19970	20701
1994	116	186	1917	1868	4192	2278	1032	1234	375	344	27	13452	11349	11172
1995	227	278	1591	3496	1395	1867	1078	465	526	61	3	10760	8891	9637
1996	294	192	1135	2606	4360	1672	2201	900	632	796	31	14526	13198	13426
1997	93	480	2205	2185	2550	3332	1729	1847	1322	612	758	17020	14334	14426
1998	155	155	2445	3228	2152	2082	2557	902	1439	885	384	16229	13629	13714
1999	57	384	1241	4459	4150	1965	1887	2351	1212	1739	1254	20641	19016	18250
2000	55	110	1880	1567	5333	3791	2004	1725	1867	1155	1546	20978	18988	21634
2001	92	109	562	2489	1814	5896	4440	2222	1583	1961	698	21773	21103	20122
2002	75	165	313	719	2293	1421	4052	3579	1922	1585	1705	17753	17275	17489

Fishing Mortality	0	1	2	3	4	5	6	7	8	9	10	4-6 Fmort	4-6 Exp Rate
1978	0.000	0.000	0.063	0.469	0.413	0.418	0.502	0.398	0.532	0.653	0.571	0.420	0.313
1979	0.000	0.001	0.104	0.301	0.448	0.381	0.368	0.175	0.391	0.166	0.358	0.427	0.317
1980	0.000	0.000	0.151	0.282	0.335	0.442	0.443	0.505	0.238	0.565	0.385	0.420	0.313
1981	0.000	0.001	0.092	0.344	0.404	0.335	0.579	0.406	0.650	0.877	0.720	0.439	0.324
1982	0.000	0.001	0.234	0.399	0.681	0.726	0.883	0.805	0.832	1.005	0.862	0.711	0.467
1983	0.000	0.010	0.332	0.524	0.735	0.494	0.427	0.338	0.376	0.501	0.414	0.624	0.425
1984	0.000	0.001	0.083	0.403	0.403	0.617	0.663	0.748	0.670	0.828	0.776	0.471	0.343
1985	0.000	0.003	0.325	0.649	0.542	0.550	0.611	0.481	0.889	0.768	0.873	0.554	0.389
1986	0.000	0.001	0.103	0.460	0.640	0.556	0.483	0.314	0.370	0.608	0.443	0.561	0.393
1987	0.000	0.002	0.266	0.426	0.440	0.366	0.446	0.379	0.336	0.397	0.358	0.432	0.320
1988	0.000	0.001	0.063	0.456	0.651	0.738	0.758	0.844	0.645	0.755	0.668	0.704	0.463
1989	0.000	0.000	0.075	0.177	0.439	0.410	0.669	0.775	0.510	0.509	0.509	0.460	0.337
1990	0.000	0.001	0.263	0.527	0.432	0.583	0.472	0.610	0.301	0.631	0.447	0.505	0.362
1991	0.000	0.001	0.161	0.547	0.716	1.037	1.004	0.879	0.635	1.379	0.758	0.843	0.524
1992	0.000	0.037	0.429	0.549	0.667	0.900	0.875	0.971	0.622	0.727	0.673	0.824	0.516
1993	0.000	0.001	0.251	0.784	0.853	0.841	1.033	1.376	1.580	2.876	1.800	0.891	0.542
1994	0.000	0.001	0.070	0.520	0.800	0.678	0.346	0.457	1.847	4.568	4.045	0.741	0.480
1995	0.000	0.000	0.031	0.122	0.230	0.194	0.070	0.052	0.032	0.481	0.052	0.191	0.158
1996	0.000	0.000	0.028	0.176	0.303	0.221	0.149	0.070	0.039	0.022	0.036	0.266	0.213
1997	0.000	0.001	0.039	0.145	0.337	0.386	0.323	0.140	0.082	0.068	0.011	0.356	0.273
1998	0.000	0.000	0.022	0.131	0.182	0.268	0.255	0.124	0.063	0.031	0.007	0.228	0.185
1999	0.000	0.001	0.040	0.154	0.183	0.152	0.126	0.129	0.085	0.010	0.043	0.168	0.141
2000	0.000	0.000	0.023	0.126	0.167	0.118	0.084	0.073	0.049	0.020	0.002	0.143	0.121
2001	0.000	0.001	0.020	0.286	0.338	0.274	0.120	0.096	0.077	0.023	0.006	0.246	0.199

Table 13. Projection results for the 2002 fishery and 2003 population using bootstrap bias adjusted point estimates with a fishing mortality in 2002 of $F_{0.1}$ =0.2.

Projected Population Number																
	2002	1500	1500	739	612	994	396	918	601	228	158	144				
	2003	1500	1228	1228	589	426	666	277	679	447	174	127				
Fishing Mortality																
	2002	0	0	0.027	0.163	0.2	0.157	0.101	0.096	0.069	0.018	0.018				
Natural Mortality																
	2002	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2				
Partial Recruitment																
	2002	0	0	0.14	0.82	1	0.79	0.51	0.48	0.35	0.09	0.09				
Begyear																
	2002	0.05	0.11	0.42	1.18	2.31	3.59	4.41	5.95	8.44	10	11.84				
	2003	0.05	0.12	0.81	1.47	2.48	3.45	4.96	6.61	8.78	12.13	13.7				
Projected Population Biomass																
	2002	75	165	313	719	2293	1421	4052	3579	1922	1585	1705	17828	17753	17588	17276
	2003	75	151	1001	865	1054	2300	1371	4488	3925	2110	1746	19087	19012	18861	17860
Projected Catch Numbers																
	2002	0	0	18	84	164	52	80	50	14	3	2				
Fishery Weights																
	2002	0.05	0.85	1.5	2.25	3.2	4.15	5.45	6.02	7.8	9.88	13.77				
Projected Catch Biomass																
	2002	0	0	27	188	524	217	438	301	108	25	33	1862	1862	1862	1835

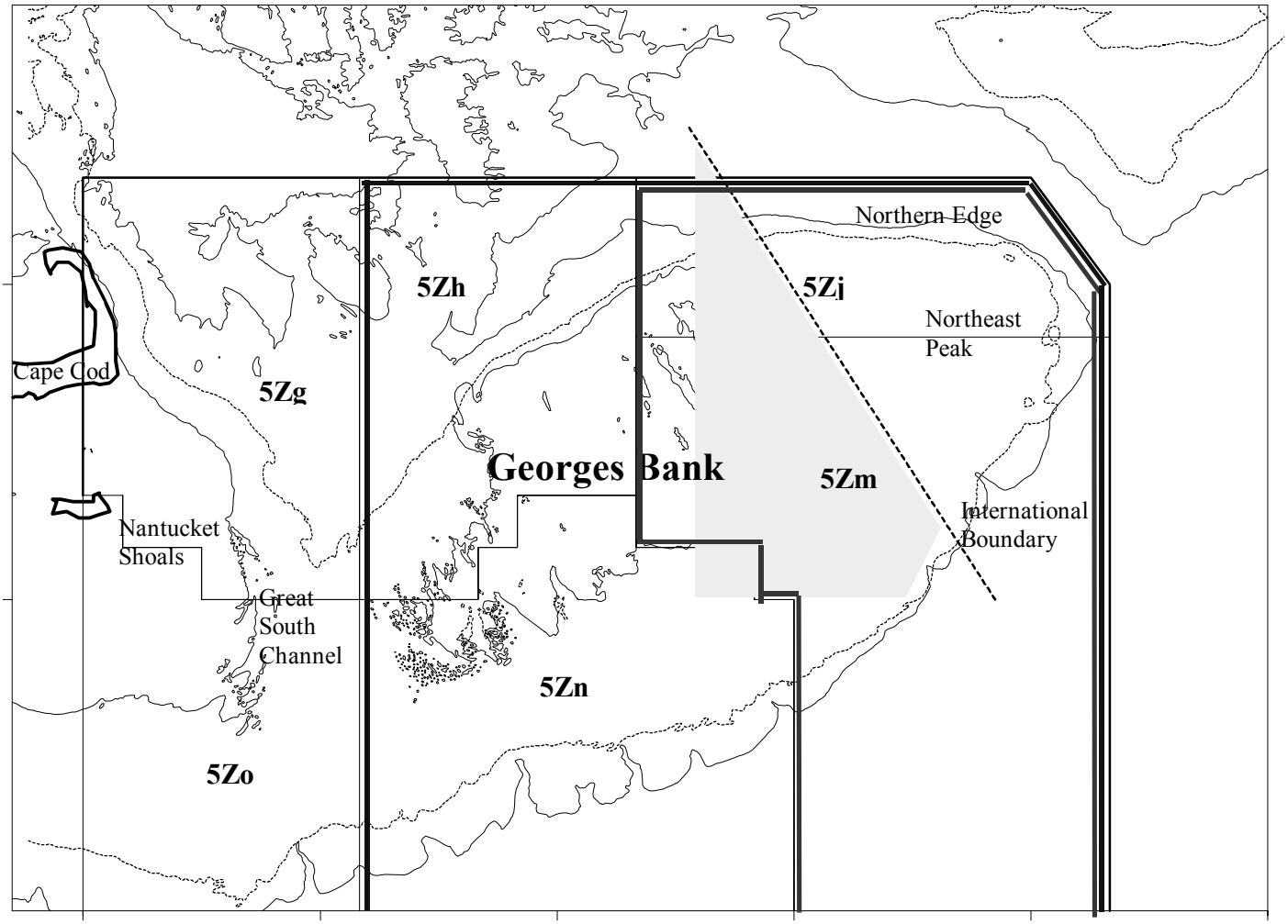

Figure 1. Map of the Georges Bank area showing the 5Zj,m management unit. Shaded area indicates USA closed area II.

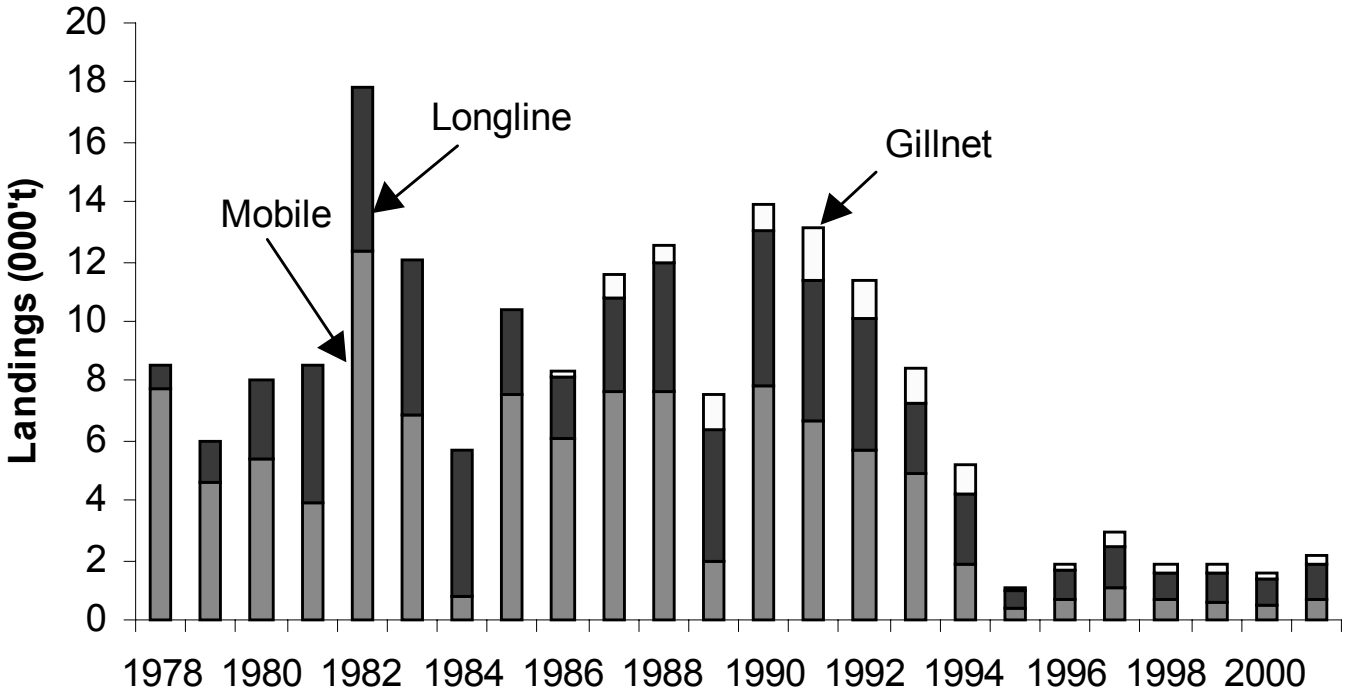

Figure 2. Landings of 5Zj,m cod by Canada gear sectors

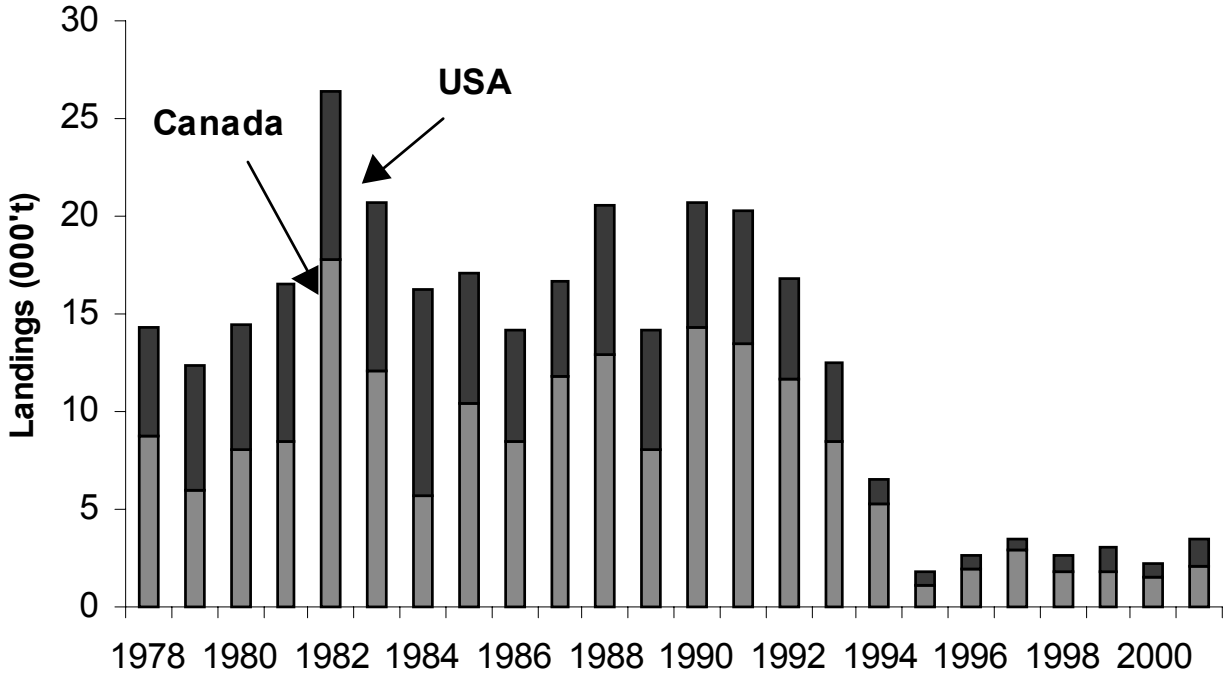

Figure 3. Landings of 5Zj,m cod by Canadian and USA fisheries.

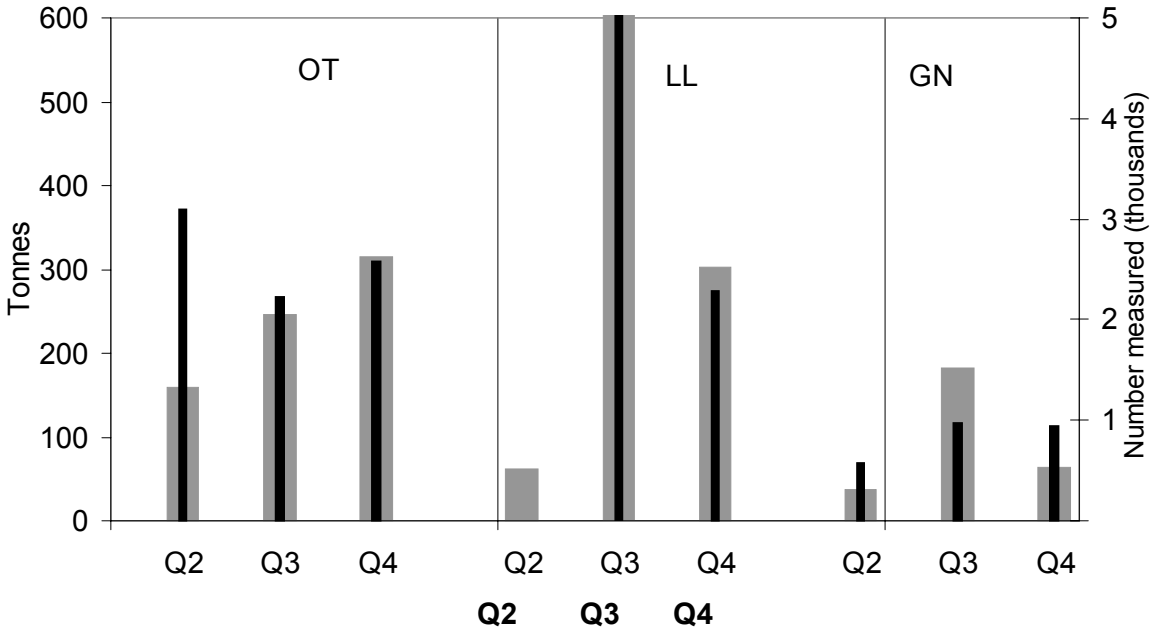

Figure 4a. Summary of Canadian landings by gear sector and corresponding length samples used in determining catch at age.

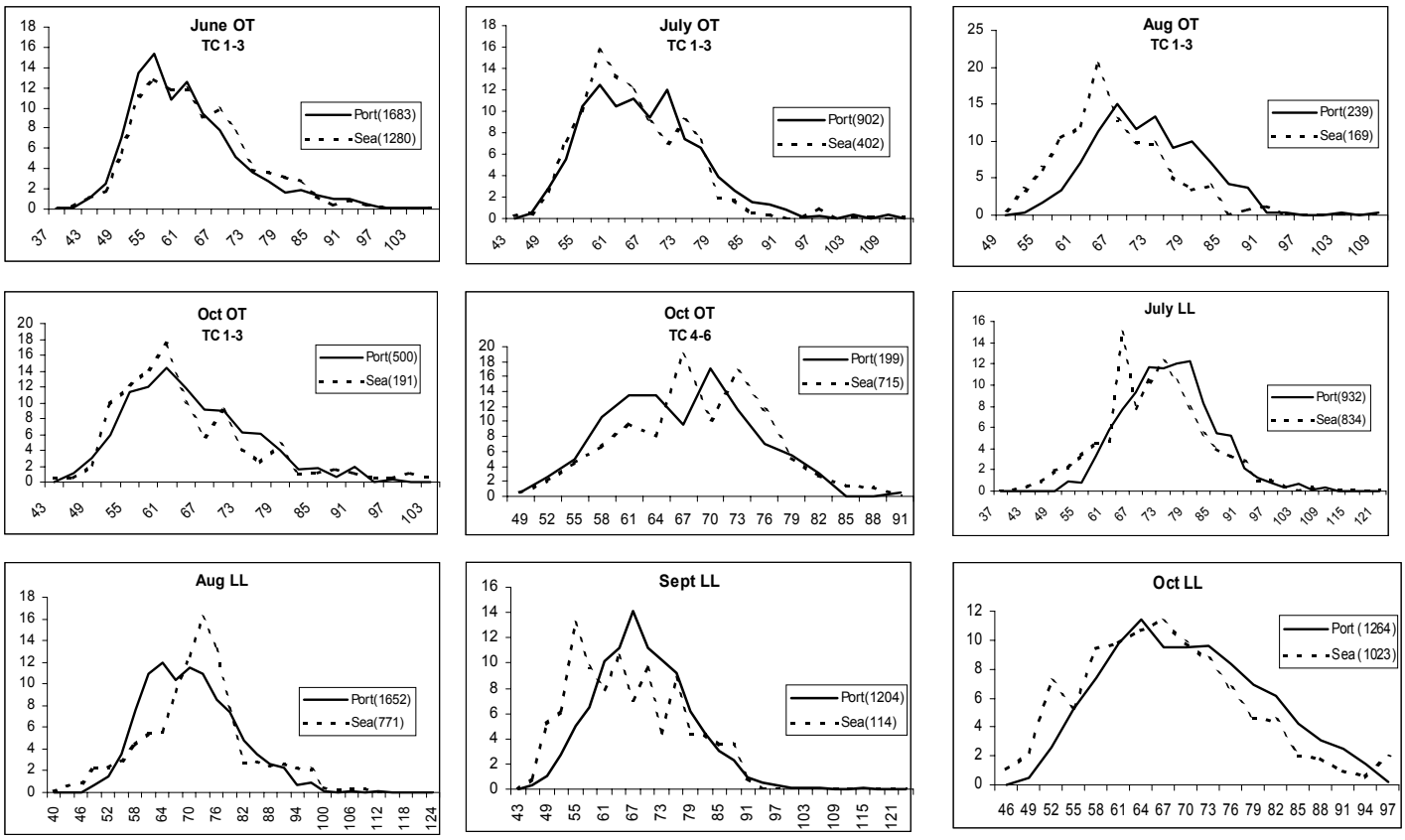

Figure 4b. Comparison of Canadian 2001 at-sea and on-shore length frequency distributions.

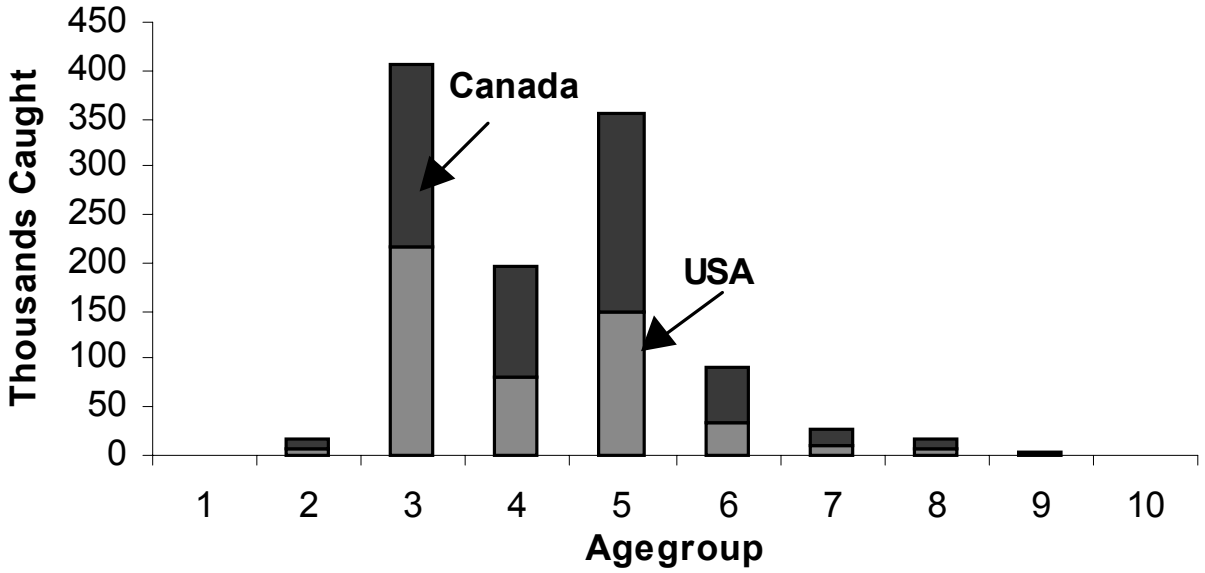

Figure 5. Catch at age in the combined Canadian and USA 5Zj,m cod fishery.

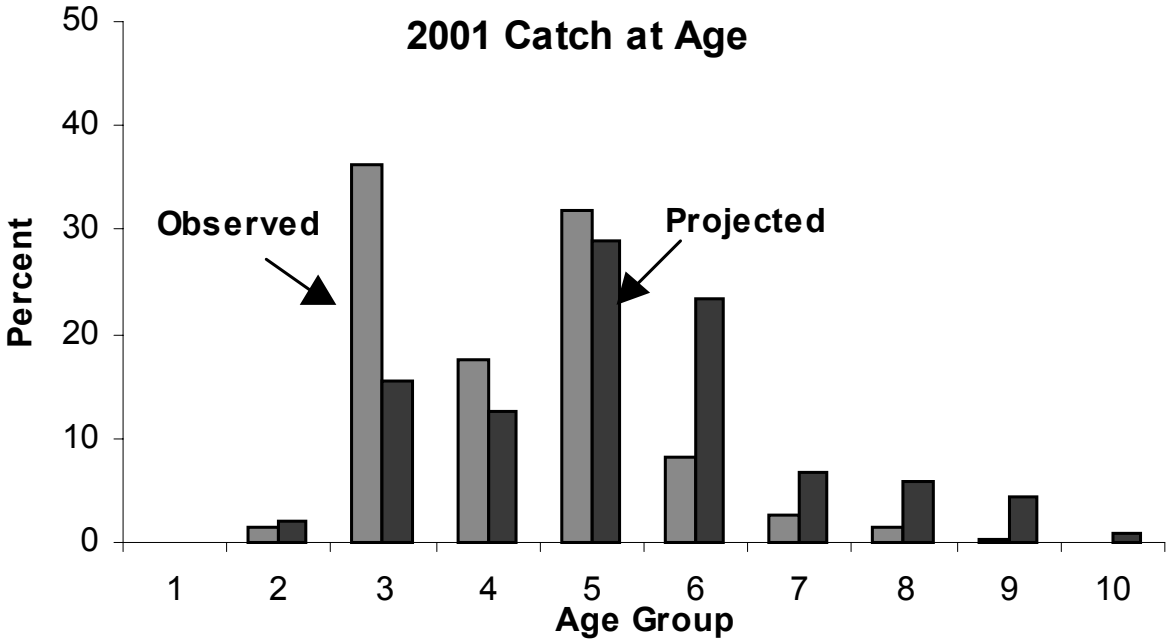

Figure 6. Observed and predicted percent catch at age for the 2001.

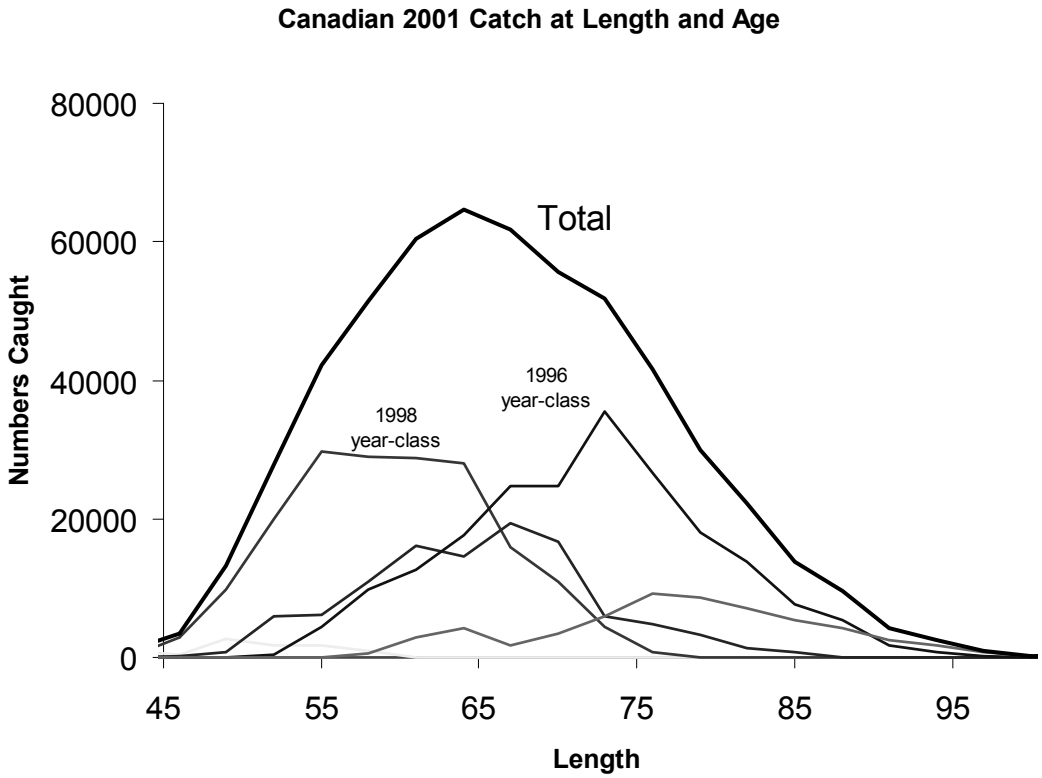

Figure 7. Length composition by agegroup for the 2001 Canadian 5Zj,m cod fishery.

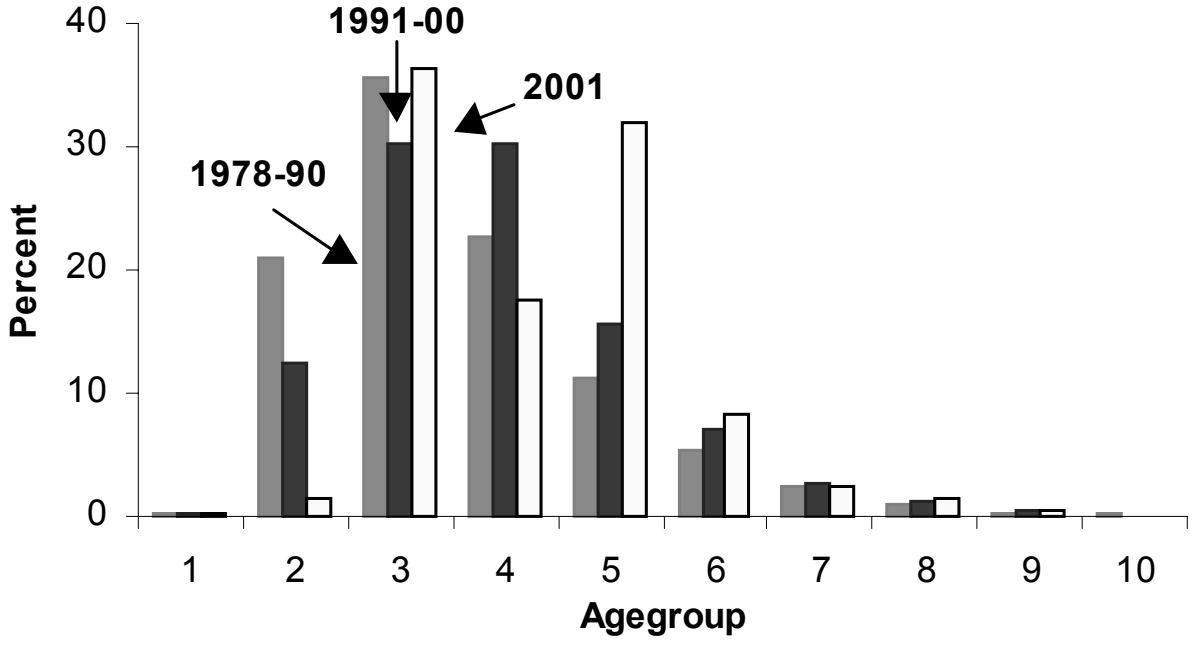

Figure 8. Comparison of the observed percent catch at age in 2001 with the percent catch at age from earlier time periods.

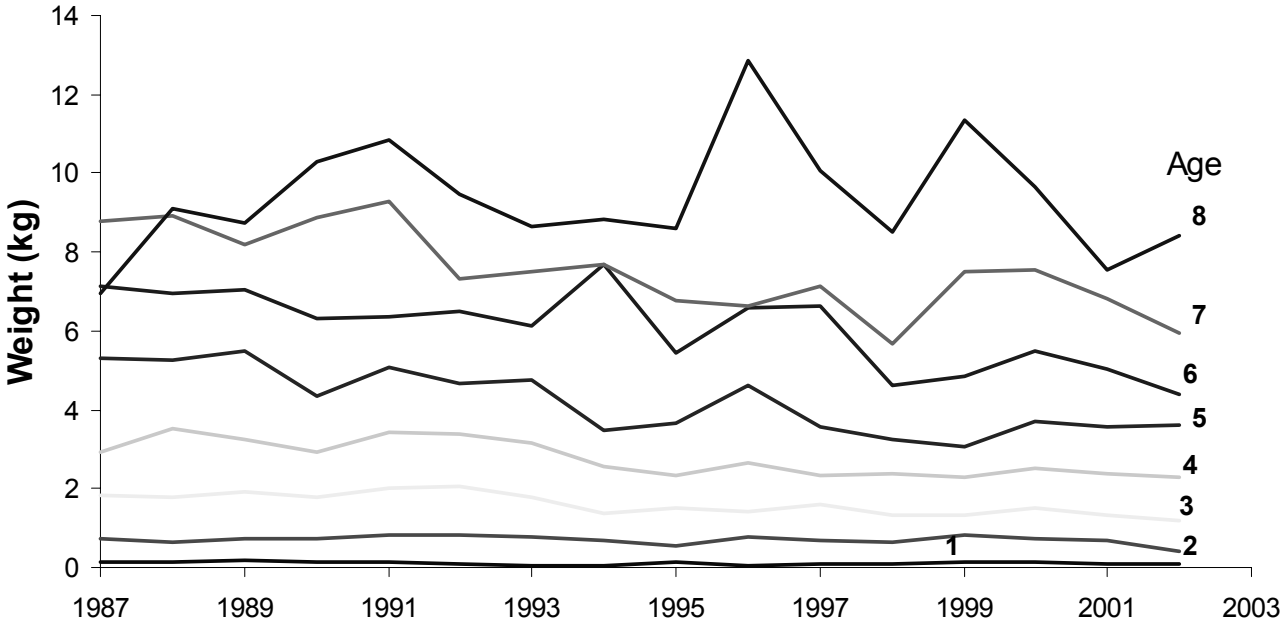

Figure 9. Beginning of year mean weight (kg) at age for cod derived from DFO research surveys.

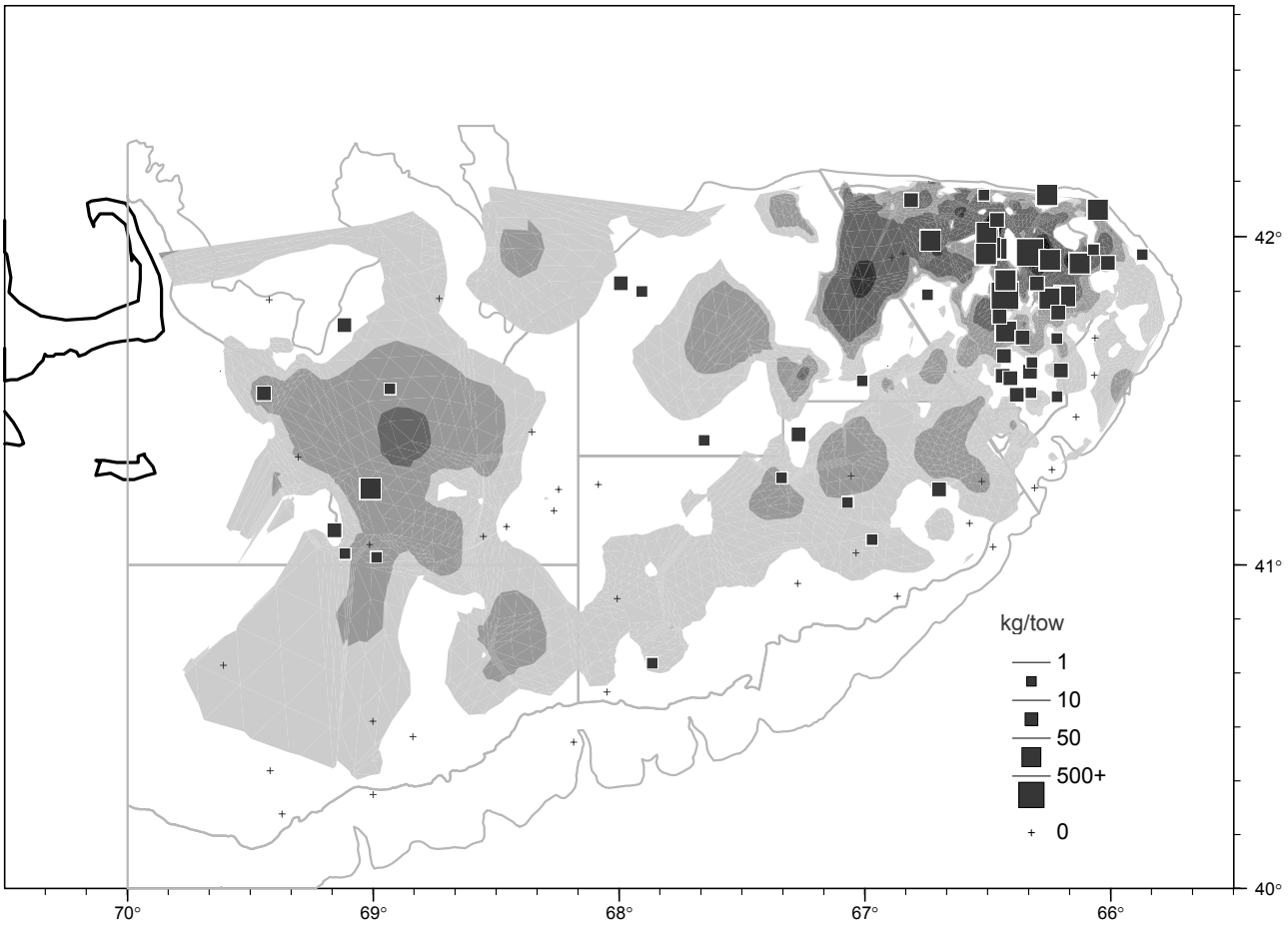

Figure 10. Comparison of cod per standard tow (kg/tow) from the 2002 DFO research survey (box symbol) with average density gradient distribution for the 1997-2001 surveys.

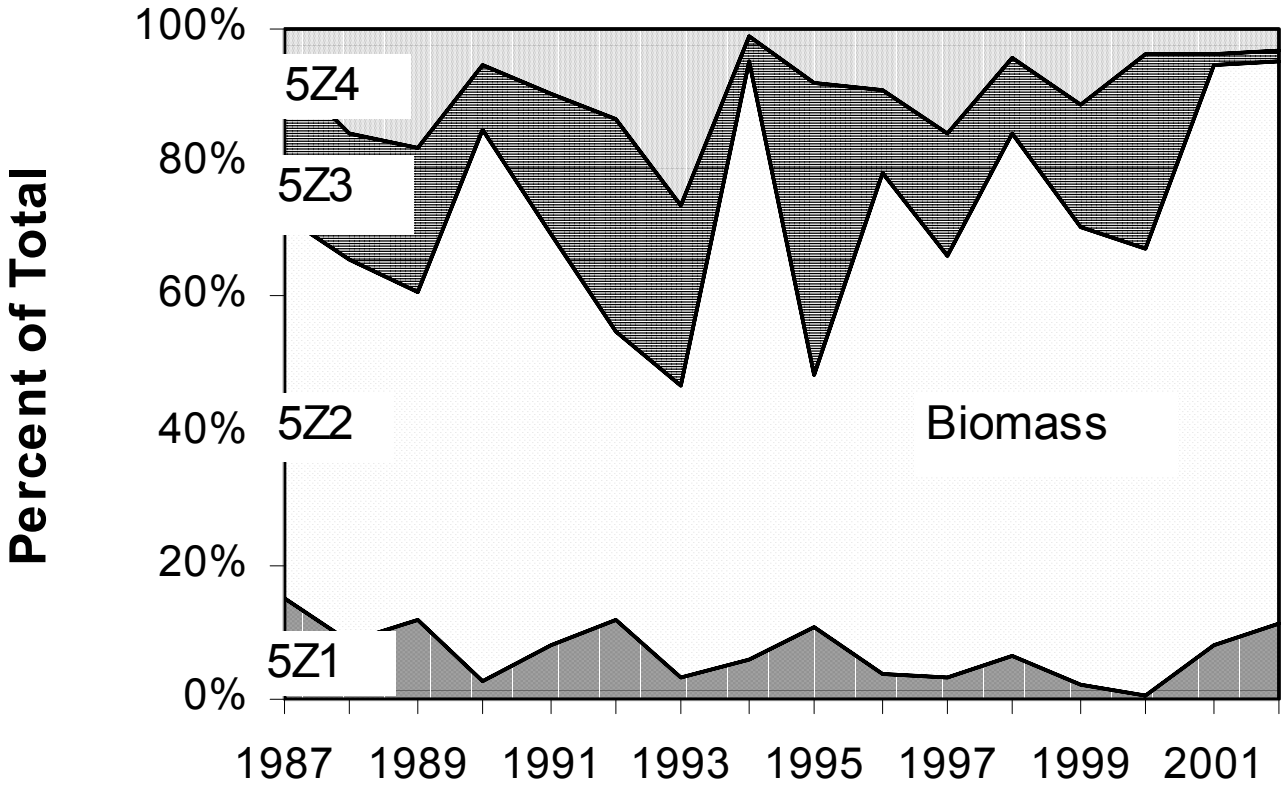

Figure 11. DFO spring survey biomass index for 1987-2002 by stratum. Area labels refer to survey strata, where 5Z1 = 50-100fm and 5Z2 = <50fm in the Canadian zone and 5Z3 and 5Z4 are in the USA zone.

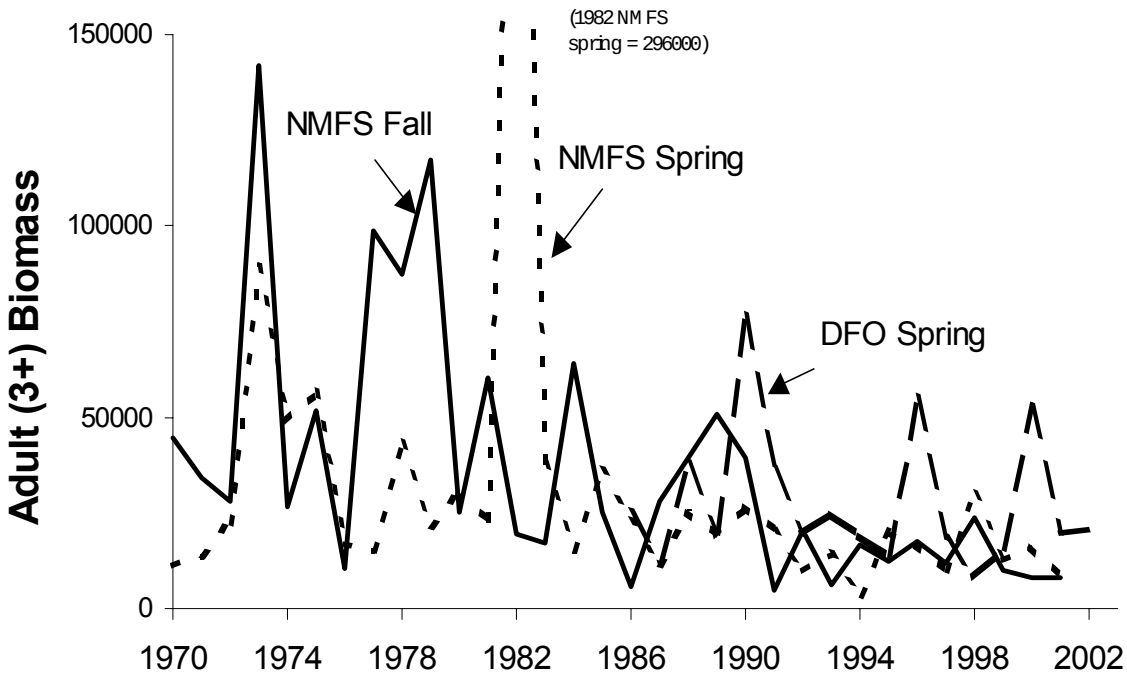

Figure 12. Estimates of adult biomass (t) indices for 5Zj,m cod from the DFO spring and NMFS spring and fall surveys in 5Zj,m.

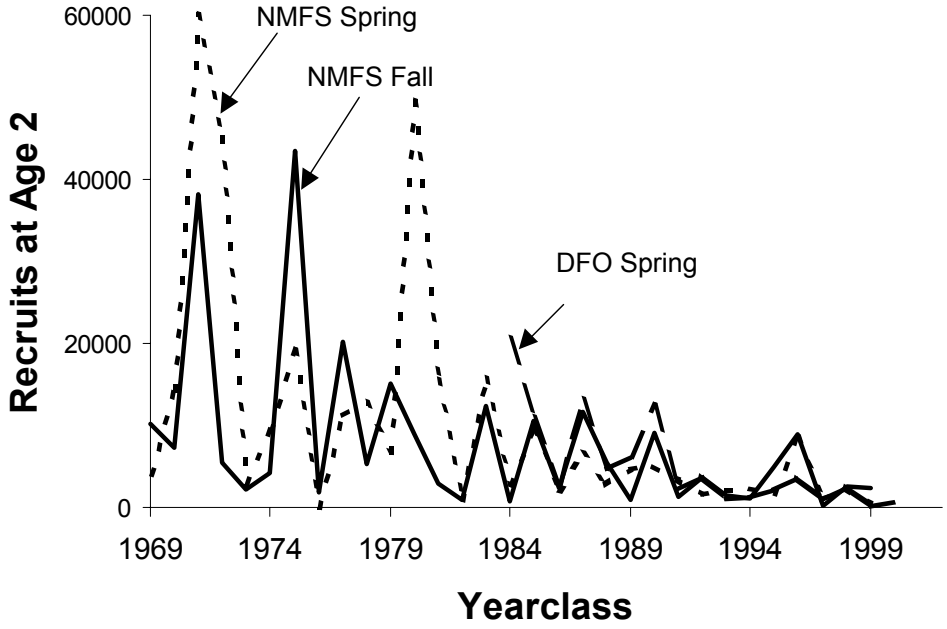

Figure 13. Estimates of recruitment at age 2 for 5Zj,m cod from the DFO spring and NMFS spring and fall surveys in 5Zj,m.

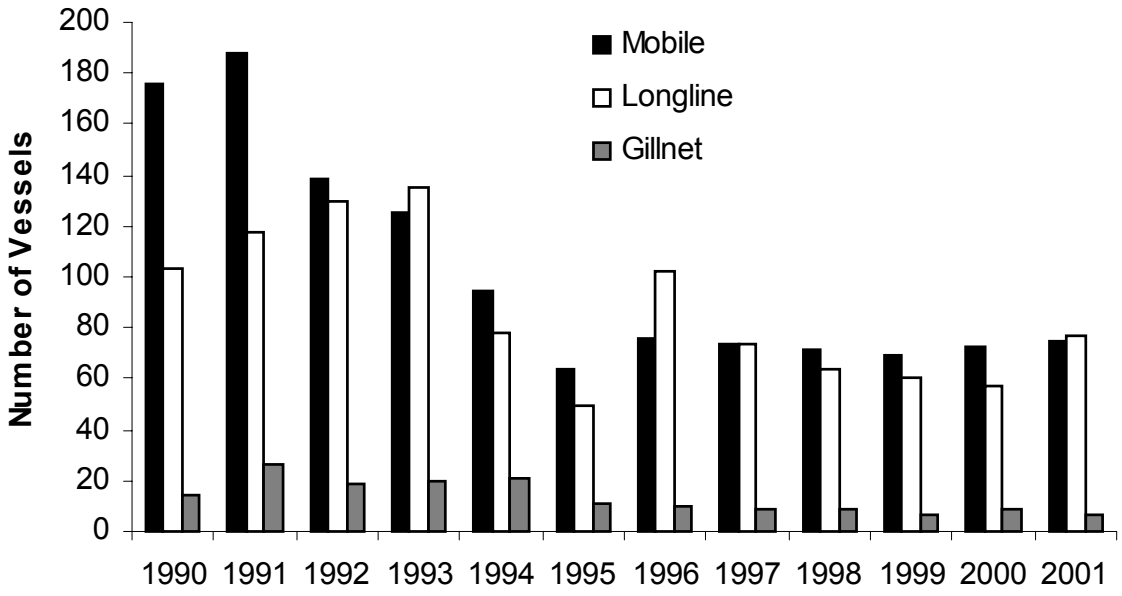

Figure 14. Number of Canadian fishing vessels by gear type.

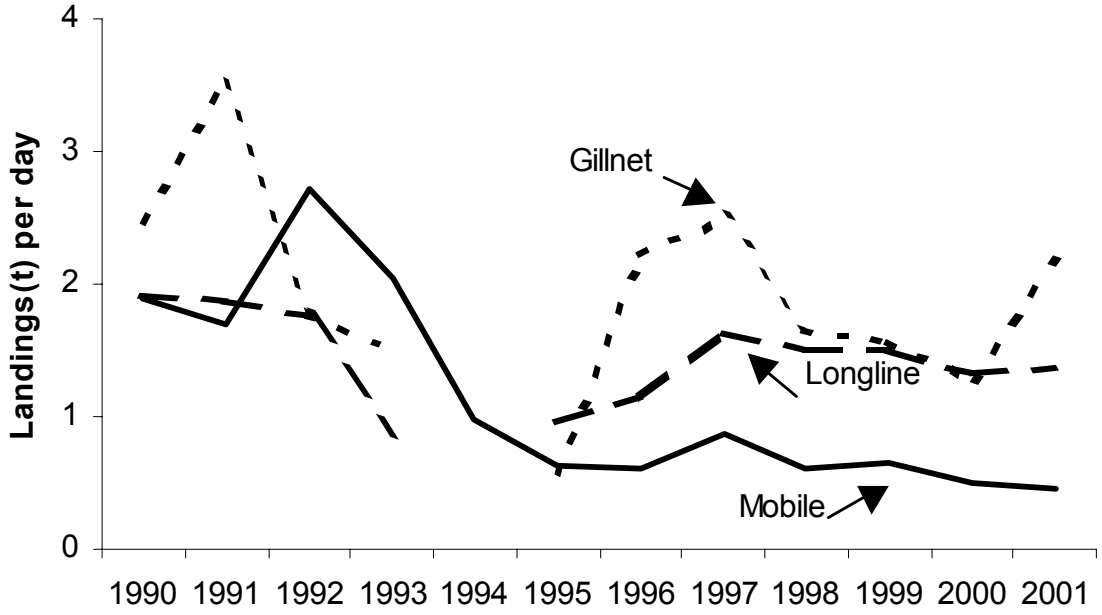

Figure 15. Landings per day fished by gear type for trips with >500kg cod landings. Effort data for 1994 fixed gear was not available.

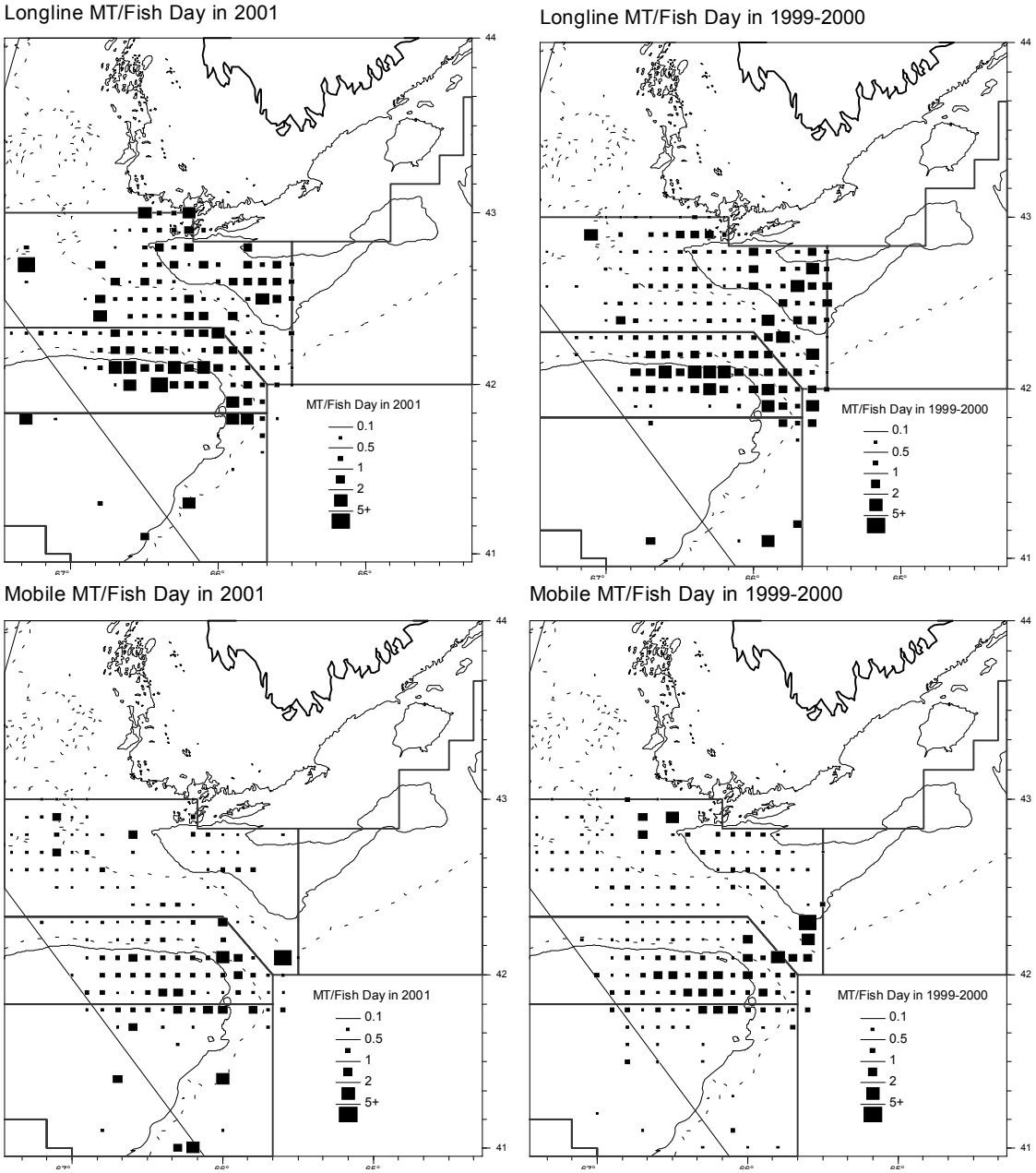

Figure 16. Spatial distribution in the Gulf of Maine area of Canadian mobile and longline fishing gear catch per day fished in 2001 versus 1999-2000.

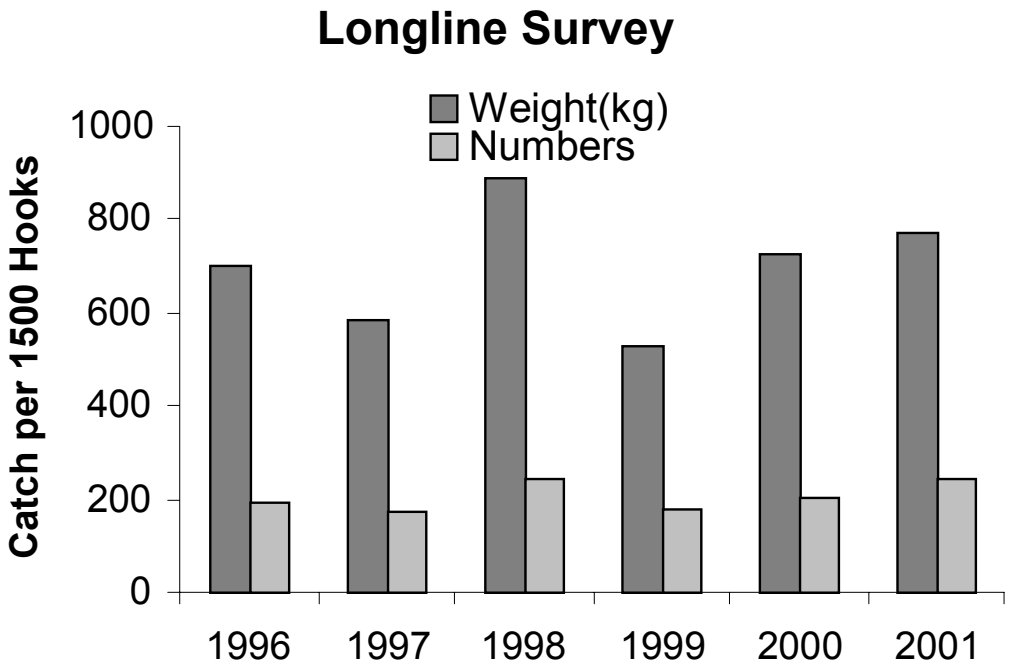

Figure 17. Results of Canadian longline industry survey showing the annual average weight and number caught per 1500 hooks.

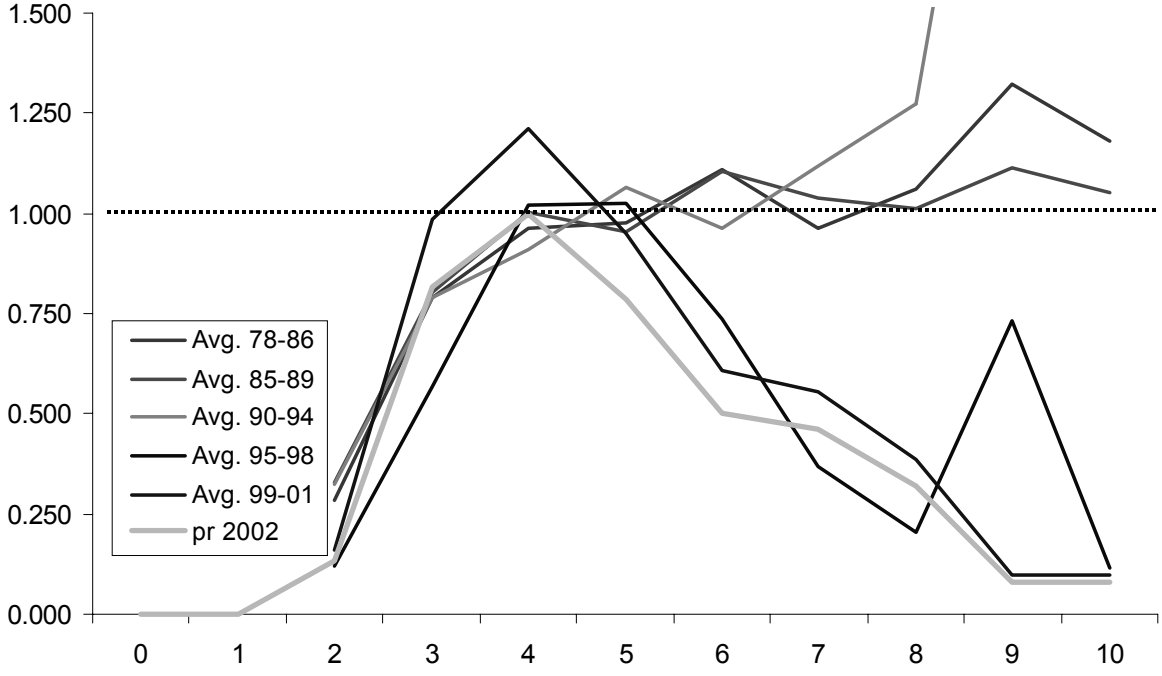

Figure18. Partial recruitment patterns for selected time periods and for 2002 (used in yield projection).

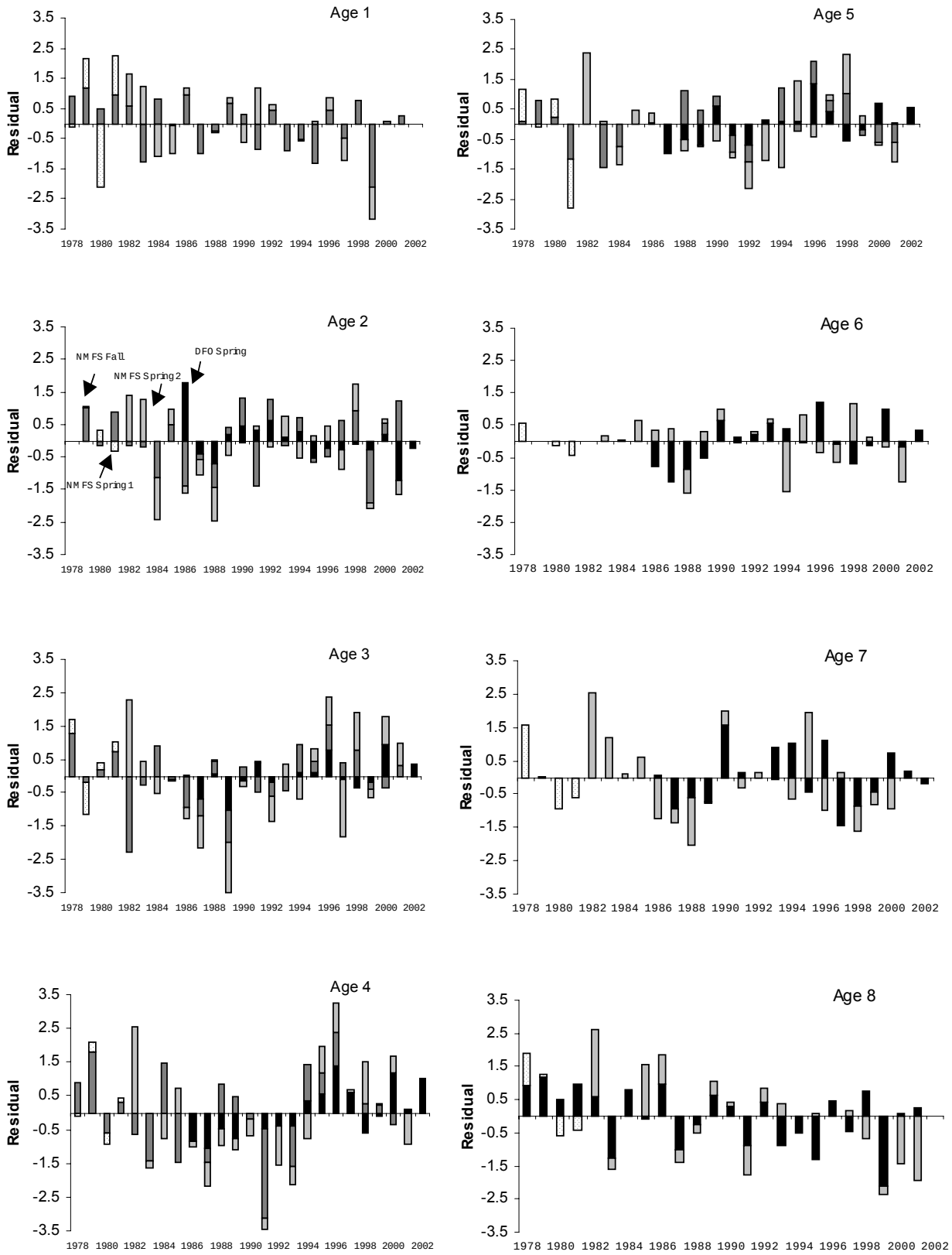

Figure 19. Standardized residuals at age from ADAPT for the DFO spring 1986-2002), NMFS fall (1977-2001), NMFS spring (1978-81,Yankee 41) and NMFS spring (1982-2001, Yankee 36) research indices.

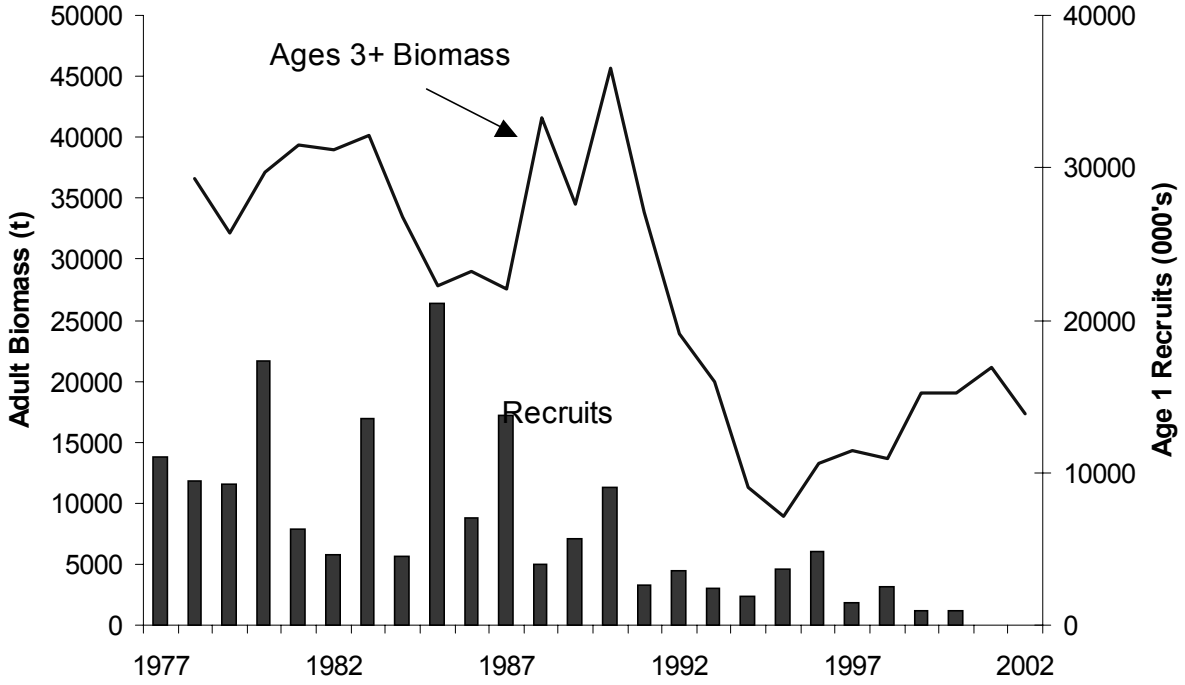

Figure 20. Spawning stock biomass and recruits at age one from ADAPT for 5Zj,m cod.

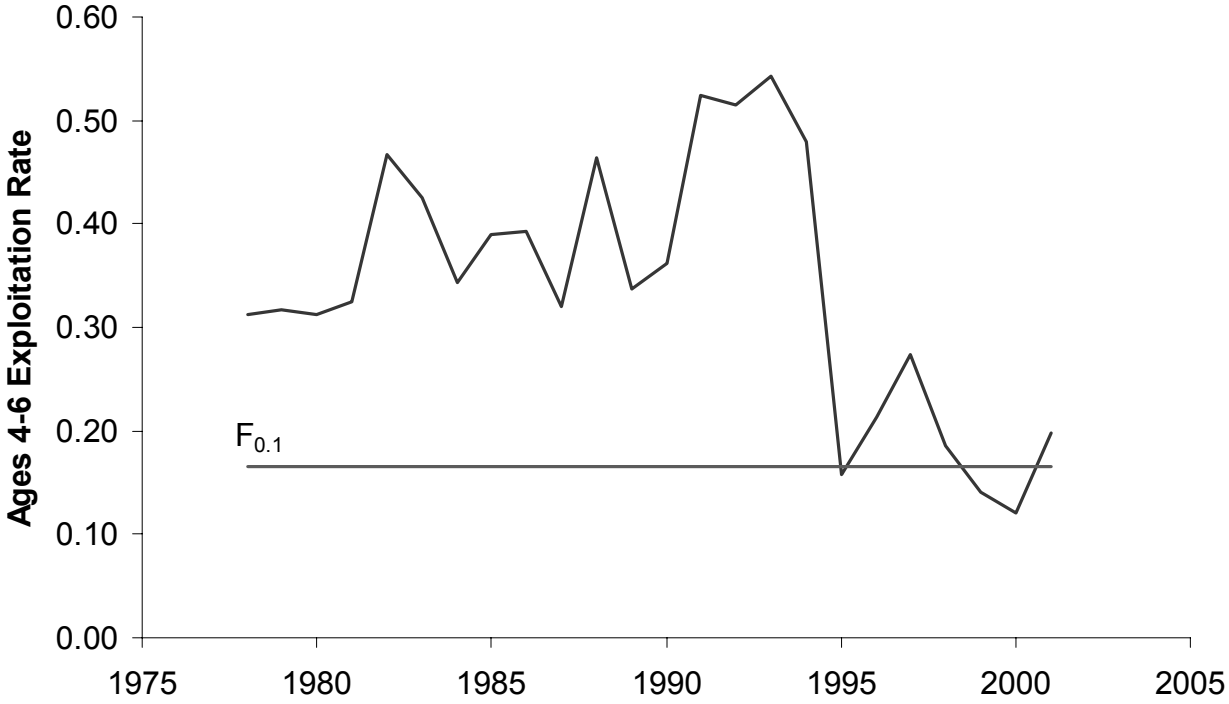

Figure 21. Exploitation rate at ages 4-6 cod derived from ADAPT.

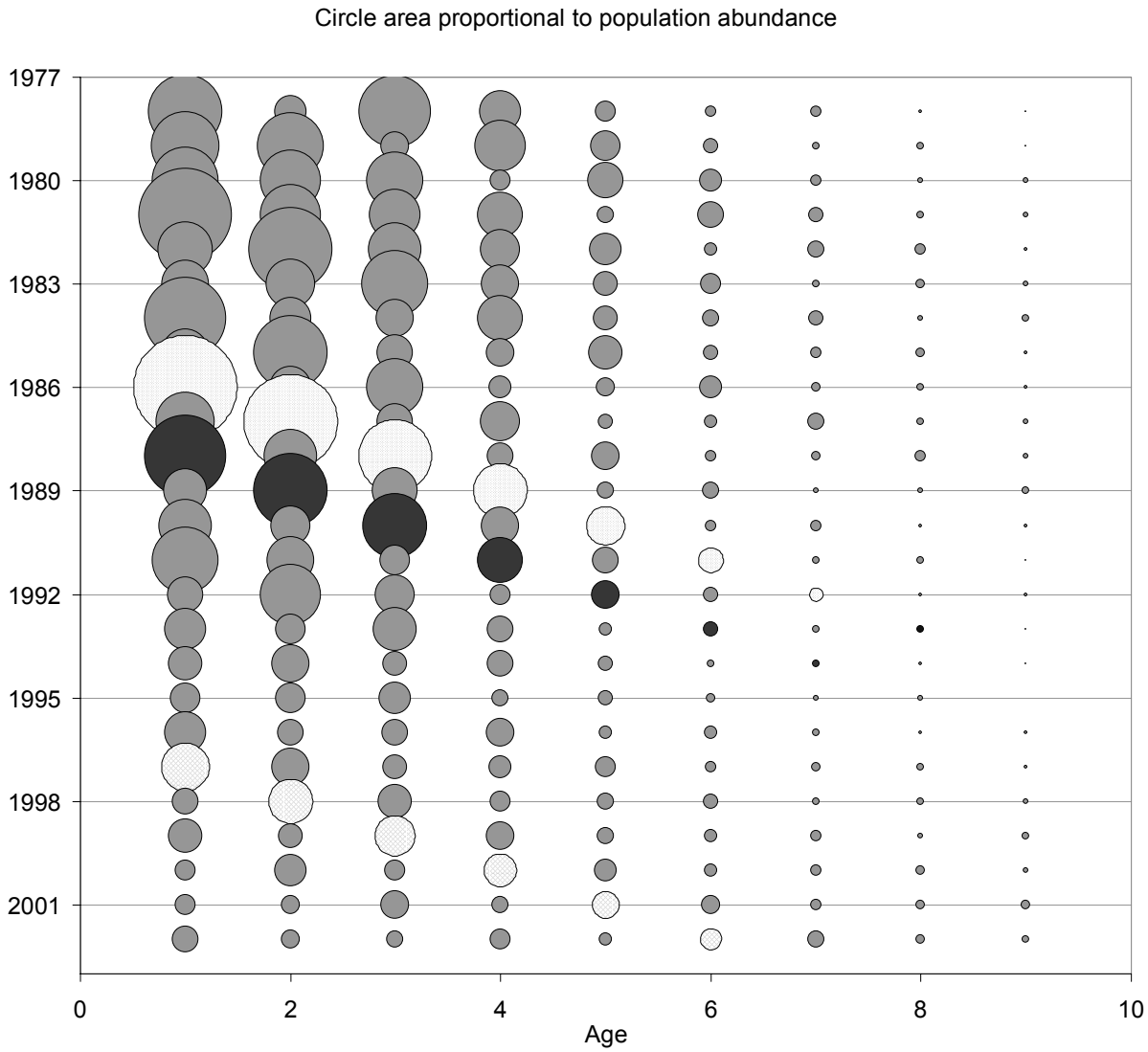

Figure 22: Relative abundance at age for 5Zj,m cod for 1978-2002.

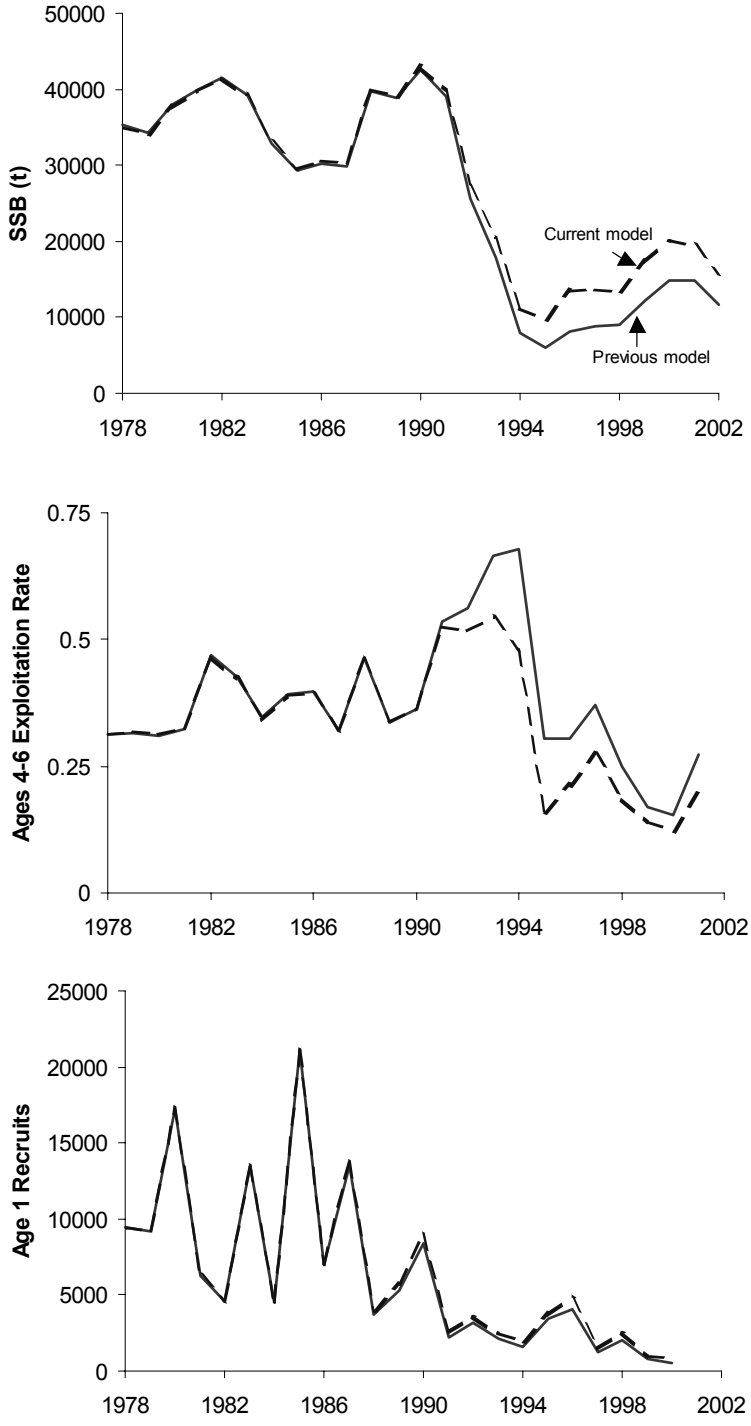

Figure 23. Comparison of population estimates derived from the current ADAPT formulation with those derived using the 2001 ADAPT formulation.

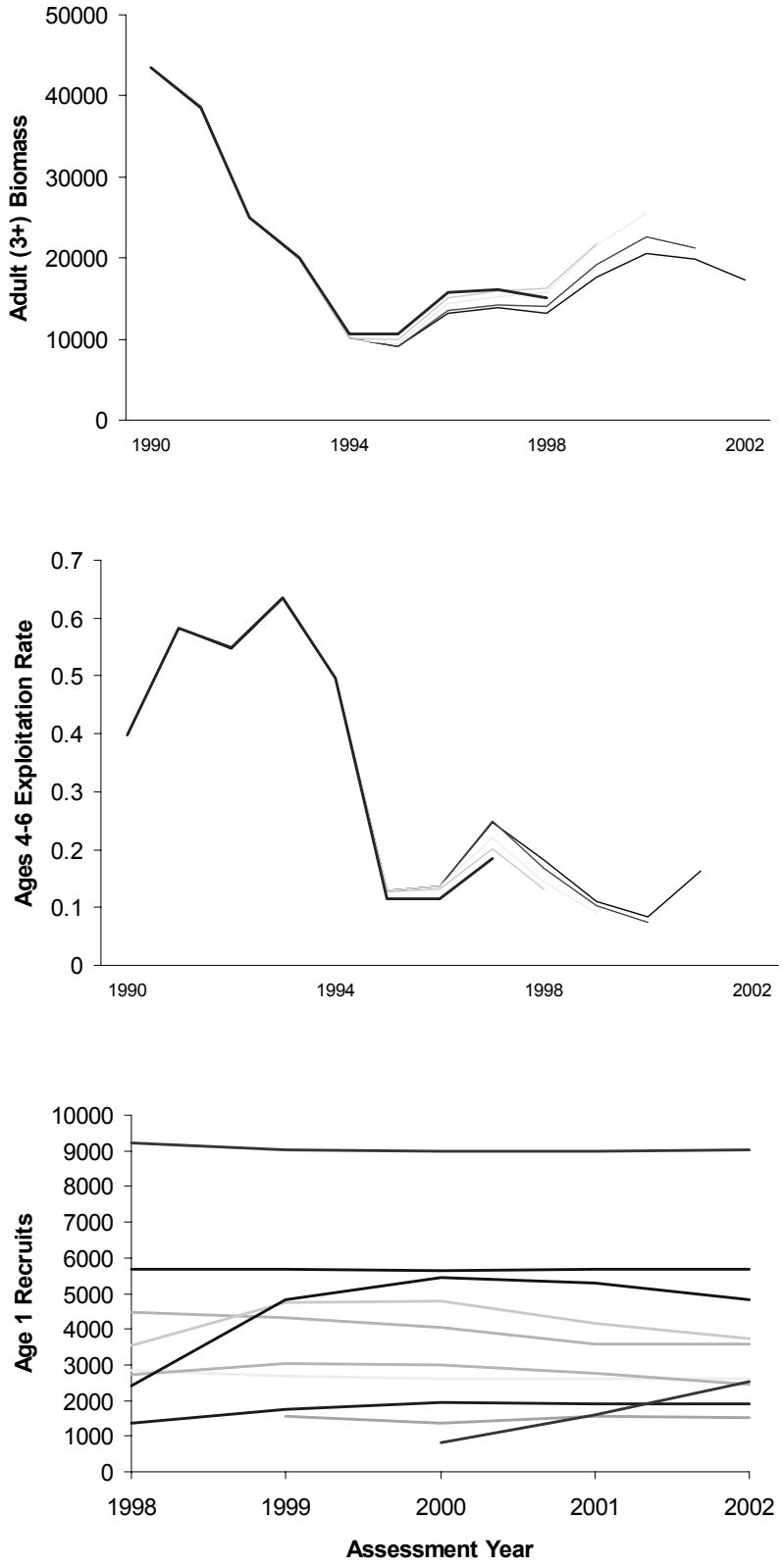

Figure 24. Retrospective pattern in population abundance (upper panel), exploitation rates on ages 4-6 (middle panel), and recruitment (lower panel) for 5Zj,m cod from ADAPT.

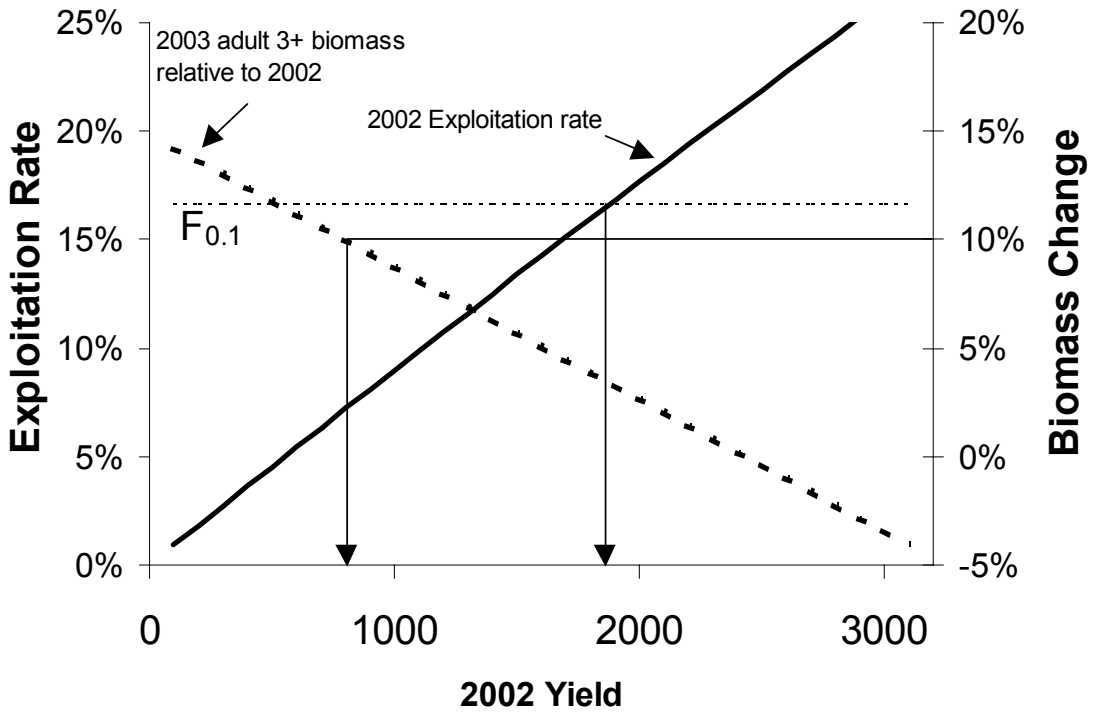

Figure 25. Projected exploitation rate and the 2003 beginning of year biomass at different levels of yield in 2002.

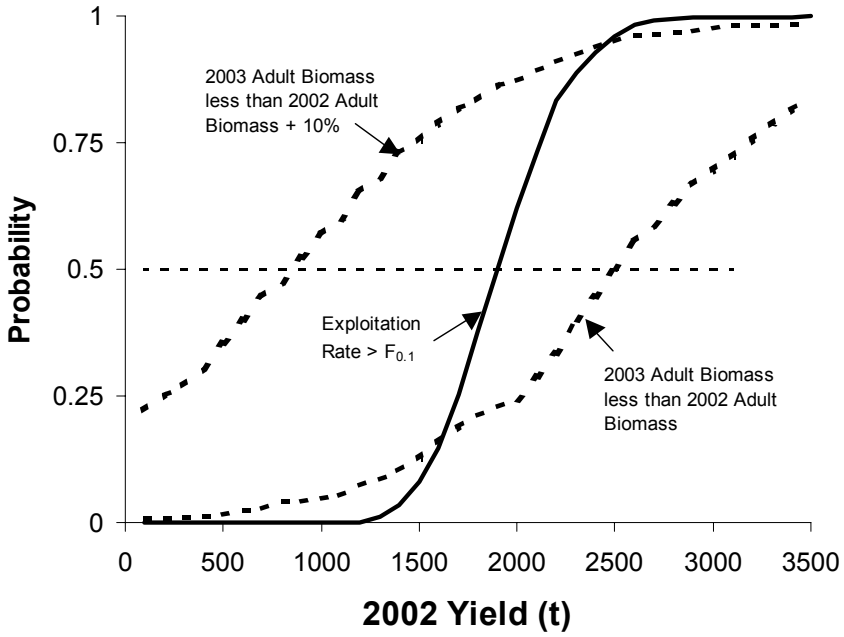

Figure 26. Probability of projected change in 5Zj,m cod spawning stock biomass from 2001 to 2002 at different yields in 2001.

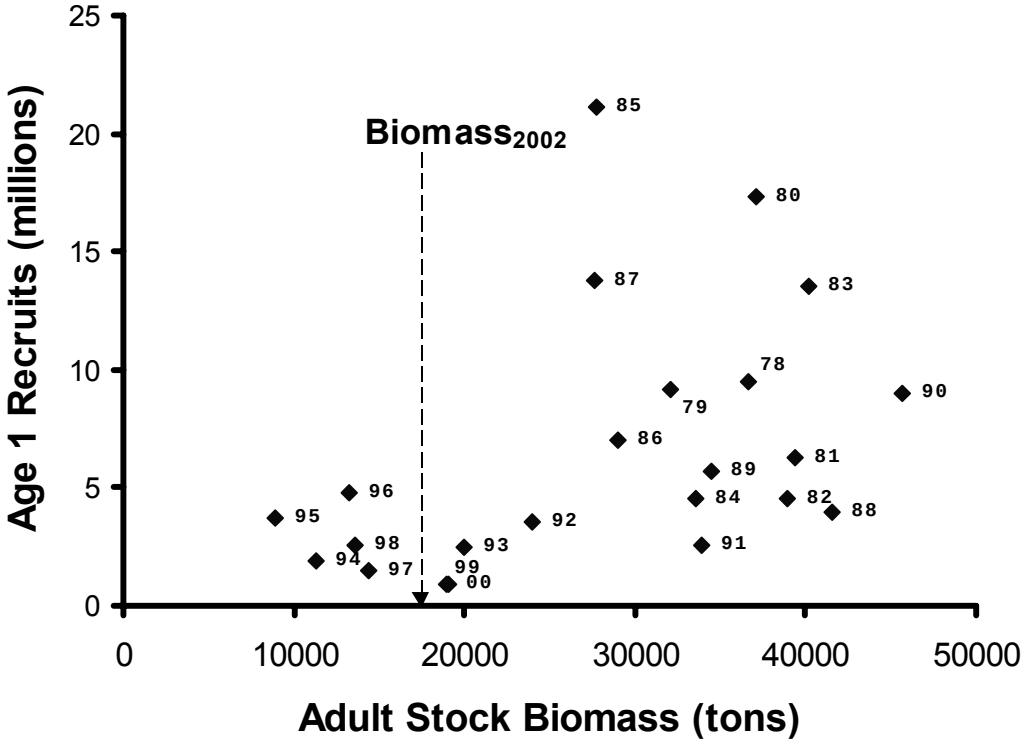

Figure 27. Comparison of recruits at age 1 and adult stock biomass for 5Zj,m cod, 1978-2002.

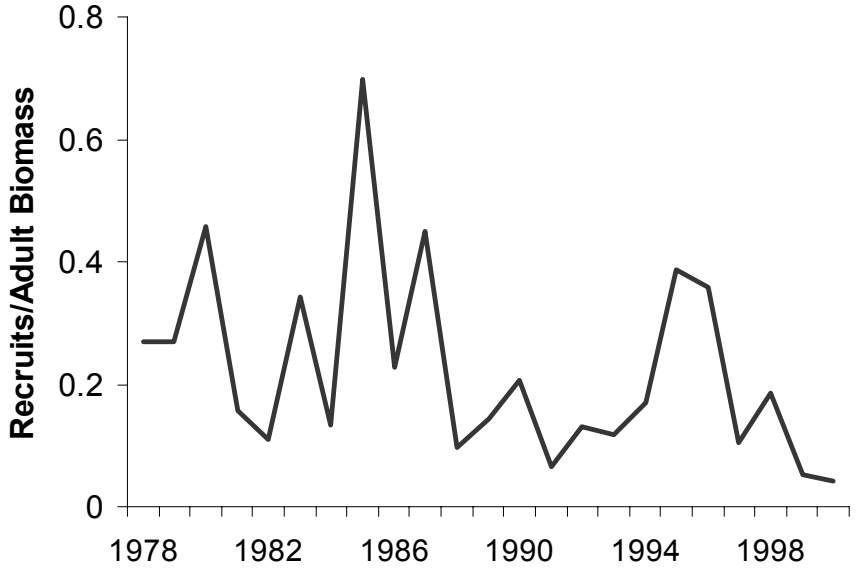

Figure 28. Relationship between recruits and spawning stock biomass (R/SSB) for 5Zj,m cod, 1978-2002.

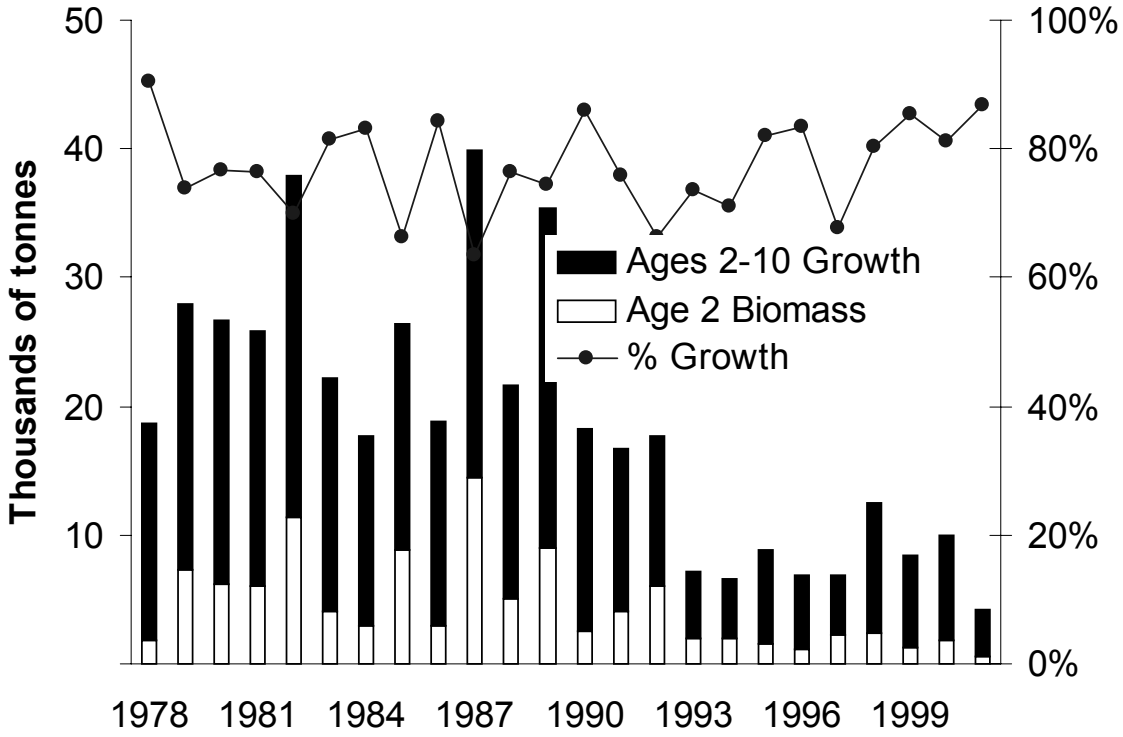

Figure 29. Comparison of stock production derived from growth and from recruitment for 5Zj,m cod, 1978-2002.

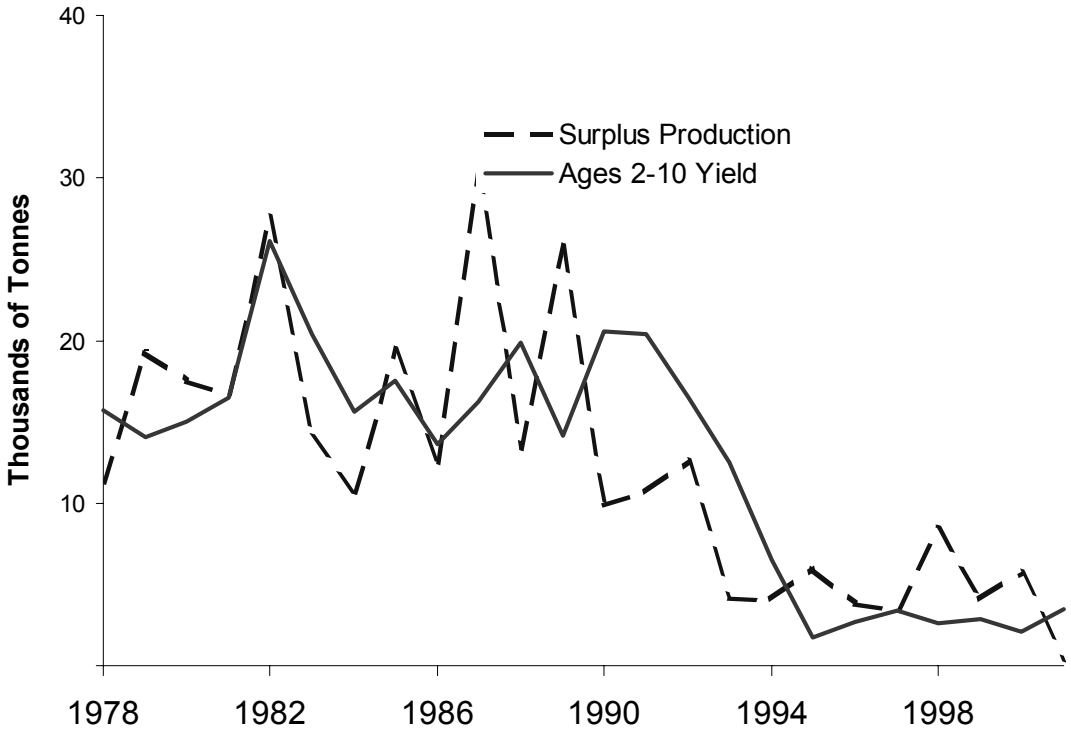

Figure 30. Surplus production and yield for 5Zj,m cod, 1978-2002